

Spring 2011

Spatial and temporal diffusion of agricultural best management practice adoption in the South Fork Shenandoah River Watershed.

Megan Renee Bauer
James Madison University

Follow this and additional works at: <https://commons.lib.jmu.edu/master201019>



Part of the [Agriculture Commons](#)

Recommended Citation

Bauer, Megan Renee, "Spatial and temporal diffusion of agricultural best management practice adoption in the South Fork Shenandoah River Watershed." (2011). *Masters Theses*. 146.
<https://commons.lib.jmu.edu/master201019/146>

This Thesis is brought to you for free and open access by the The Graduate School at JMU Scholarly Commons. It has been accepted for inclusion in Masters Theses by an authorized administrator of JMU Scholarly Commons. For more information, please contact dc_admin@jmu.edu.

Spatial and temporal diffusion of agricultural best management practice adoption
in the South Fork Shenandoah River watershed.

Megan Renee Bauer

A thesis submitted to the Graduate Faculty of

JAMES MADISON UNIVERSITY

In

Partial Fulfillment of the Requirements

for the degree of

Master of Science

Integrated Science and Technology

May 2011

To my family

ACKNOWLEDGMENTS

Many thanks to:

My thesis adviser, Dr. Maria Papadakis, for providing me guidance and advice throughout the writing process. Dr. Papadakis' direction and wealth of knowledge about the Watershed was vital to the successful completion of this thesis.

Dr. Michael Deaton, for teaching me so much in my undergraduate education and still supporting me during my Masters' work. Dr. Deaton's advice and teaching was central to the successful completion of the spatial analytical portions of this thesis.

My work supervisors, Mr. Abram Kaufman and Mr. Gary Shears, for their support of my efforts to complete this Master's work while I also worked as Sustainability Coordinator for James Madison University's Office of Facilities Management. I thank them for all they have done; their patience and kind support has been essential to the successful completion of my Master's work.

My family, especially my parents, Bill and Lisa Bauer for their constant encouragement and support of my many personal, educational, and professional goals. They have kept me motivated through the writing process and have been a constant source of positive enthusiasm. Thanks to my brother and sister, Jason Bauer and Sarah Bauer, for helping me keep my sense of humor and keeping me motivated. Thanks also to my aunt and uncle, Karen and Rick Fauber, for being so supportive of me through my many years of education. Without all of my family as a strong support system, this Masters' work would not have been possible. My thanks and love goes out to all of my family for loving, teaching, and supporting me through the years.

TABLE OF CONTENTS

Acknowledgments.....	iii
List of Tables.....	vi
List of Figures	vii
Abstract	viii
1. Introduction	1
1.1 <i>Background.....</i>	5
1.2 <i>Intensive Agricultural Activities and the role of BMPs</i>	9
1.3 <i>Summary, Methods, and Data</i>	12
2. The Diffusion of Innovation.....	14
2.1 <i>Innovation Diffusion: A Brief Definition</i>	15
2.2 <i>The Innovation Adoption Decision Process.....</i>	15
2.3 <i>Innovation Properties</i>	20
2.4 <i>The Social System, Communication Channels, & Diffusion.....</i>	21
2.5 <i>Patterns of Spatial Diffusion</i>	26
2.6 <i>Implications of the Literature for agricultural BMP Adoption and Diffusion</i>	30
3. diffusion and characteristics of BMPS	33
3.1 <i>History of Virginia's Promotion of BMPs</i>	34
3.2 <i>BMPs in the South Fork Shenandoah River Watershed</i>	38
3.3 <i>BMPs in the Study Area.....</i>	43
3.4 <i>Farmer Receptions to BMP Conservation Programs</i>	49
3.5 <i>Summary and Implications</i>	52
4. Findings & Discussion.....	56
4.1 <i>Temporal Diffusion of BMP adoption in the Study Area</i>	57
4.2 <i>Spatial Diffusion of BMP adoption in the Study Area</i>	63
4.2.1 <i>Average Nearest Neighbor Analysis</i>	68

4.2.2 Parcels' BMP Adoption densities	70
4.3 <i>Summary of Temporal and Spatial Analyses</i>	74
5. Further Research & Conclusions	79
Appendix 1. Map Sequences of Diffusion of BMP Adoption	81
References	92

LIST OF TABLES

Table 1. Description and Frequency of BMPs in the South Fork Shenandoah Watershed.....	39
Table 2. Description of the BMPs in the study area and their frequencies.	45
Table 3. Quantities of adoption events of different BMP categories in the study area and the watershed.	46
Table 4. Chart showing the different intensities of properties for different BMP types.	48
Table 5. Results on Average Nearest Neighbor Statistical Test.	69
Table 6. Description and Summary of the number and size of farms in each ZIP code of the analysis	71

LIST OF FIGURES

Figure 1. Map showing location of the Study area within the United States.	3
Figure 2. Map showing the tributaries and streams of the watershed.....	5
Figure 3. Map showing boundary and counties of the South Fork Shenandoah River watershed.....	6
Figure 4. Total VACS BMPs Projects in the South Fork Shenandoah Watershed, 1989-2008	8
Figure 5. Categorization of adopters based on innovativeness. Source: (Rogers, 1983).....	17
Figure 6. Three types of Spatial Diffusion. Adapted from source: (Morrill, Gaile, & Thrall, 1988)	28
Figure 7. Graph of annual funding for VACS, 1989-2008. Source: DCR.....	37
Figure 8. Map showing point data of BMP distribution within the watershed..	42
Figure 9. Map Showing the ZIP codes comprising the study area.	44
Figure 10. Graph of bell-shaped and S- shaped curves depicting diffusion of adoption of an innovation over time. Source: (Rogers, 1983).....	58
Figure 11. Total BMP participation including all BMPs in the study area from 1989-2008.....	59
Figure 12. BMP Adoption in the Study Area, by BMP type, 1989-2008.....	61
Figure 13. Map Sequence: diffusion of all BMPs cumulatively in the study area, 1989-1994.	64
Figure 14. Map Sequence: diffusion of all BMPs cumulatively in the study area, 1995-2000.	65
Figure 15. Map Sequence: diffusion of all BMPs cumulatively in the study area, 2001-2006.	66
Figure 16. Map Sequence: diffusion of all BMPs cumulatively in the study area, 2007-2008.	67
Figure 17. Sample of the map from analysis of BMP adoption intensity for each parcel in the study area. .	70
Figure 18. Map Sequence: diffusion of buffer BMPs cumulatively in the study area, 1996-2008.....	73
Figure 19. Map Sequence: diffusion of buffer BMPs cumulatively in the study area, 1996-2008.....	82
Figure 20. Map Sequence: diffusion of cover crop BMPs cumulatively in the study area, 1989-2008	83
Figure 21. Map Sequence: diffusion of cropland drainage BMPs cumulatively in the study area, 1989-2008	84
Figure 22. Map Sequence: diffusion of livestock exclusion BMPs cumulatively in the study area, 1989-1998.....	85
Figure 23. Map Sequence: diffusion of livestock exclusion BMPs cumulatively in the study area, 1989-1998.....	86
Figure 24. Map Sequence: diffusion of nutrient management BMPs cumulatively in the study area,	87
Figure 25. Map Sequence: diffusion of permanent cover BMPs cumulatively in study area, 1989-1998.....	88
Figure 26. Map Sequence: diffusion of permanent cover BMPs cumulatively in study area, 1999-2008.....	89
Figure 27. Map Sequence: diffusion of waste management BMPs cumulatively in the study area, 1989-1999.....	90
Figure 28. Map Sequence: diffusion of waste management BMPs cumulatively in the study area, 2000-2008.....	91

ABSTRACT

This research visualizes, describes, and analyzes the unique spatial and temporal diffusion of agricultural best management practices adopted within the South Fork Shenandoah River Watershed during the twenty year period from 1989 to 2008. The Shenandoah River is a tributary of the Potomac River, which in turn flows directly into the Chesapeake Bay. The findings and research presented here could aid policy makers, conservation technicians, and Soil and Water Conservation District agents to better plan promotions and funding for cost share BMPs. This research identifies motivations and influential forces that are inherent in the BMPs, in the social system, and in the geographic location of the subset of ZIP codes in the Watershed that had intense BMP adoption activity. This analysis of BMP adoption activity in this study area of the Watershed revealed the following possible forces that may have influences the clustering of BMP adoption events in the study area: 1.) geographical and hydrological mechanisms of the location of the study area, 2.) promotion of priority practices by government agencies, 3.) properties of the BMPs that influence their adoptability, and 4.) the dynamics of hierarchical contagion diffusion.

1. INTRODUCTION

This research visualizes, describes, and analyzes the unique spatial and temporal diffusion of agricultural best management practices adopted within the South Fork Shenandoah River Watershed (herein referred to as *the Watershed*) during the twenty year period from 1989 to 2008. The Shenandoah River, which consists of the North Fork, the South Fork, and the Mainstem is a tributary of the Potomac River, which in turn flows directly into the Chesapeake Bay, see Figure 1.

The course of the South Fork Shenandoah River's lower order streams and small tributaries runs through intensively active agricultural lands. Out of the 1,070,105 acres of land in the Watershed, 38% of the total acreage, 401,577 acres, is considered farmland (Mizel, Papadakis, Degner, Shepard, & Havinga, 2008, p. 4). This compares with urban acreage at 4% and forest acreage at 58% of the total Watershed acreage (Mizel, Papadakis, Degner, Shepard, & Havinga, 2008). Of the total farm acreage of the Watershed 51%, or 232,449 acres, of the farmland is dedicated to cropland (US Department of Agriculture, National Agricultural Statistics Service, 2002). There are 3,132 farms in the Watershed with the average sized farm being 146 acres. Cattle are being raised on 67% of the farms in the Watershed, on an estimated 2,104 farms (US Department of Agriculture, National Agricultural Statistics Service, 2002).

Intensive agricultural activities, such as those present in the South Fork Shenandoah River Watershed, are known to contribute to sediment loading, microbial contamination, and chemical pollution. This contamination and pollution is important to address in any watershed, but doubly important for the South Fork Shenandoah Watershed because it

empties into the Chesapeake Bay, a sensitive and vital estuary. These negative inputs into surface waters can be controlled and significantly reduced through the wide and frequent use of best management practices (BMPs). Currently the agricultural BMPs that address soil and water conservation and protection are voluntary and are not obligatory for farmers to practice. Studying the diffusion patterns of BMPs in the Watershed can identify of how BMPs can be more effectively promoted and funded for widespread successful adoption events within the watershed. More successful promotion campaigns, leading to more widespread and dedicated use of BMPs, will help to mitigate agricultural impacts on the local watershed as well as the on Bay health.



Figure 1. Map showing location of the South Fork Shenandoah River Watershed within the United States. Source: ESRI

This thesis comprises a detailed literature review on BMP adoption, innovation diffusion theory, rural sociology and innovations, and properties of innovations. Also included in this thesis is an in-depth study of the temporal and spatial diffusion patterns of BMP adoption activity in a subset of ZIP codes within the Watershed that have high instances of BMP adoption events (this subset is herein referred to as the *study area*).

These ZIP codes with high instances of BMP adoption events were previously identified in the Rapid Watershed Assessment (RWA) conducted by Mizel, Papadakis, Degner, Shepard, & Havinga (2008). The RWA found that the difference between these ZIP codes with intensive BMP adoption and the other ZIP codes of the Watershed could not be explained merely by standard farm statistics alone (i.e. size of farm, wealth of farm, farm operator demographics, etc.) (Mizel, Papadakis, Degner, Shepard, & Havinga, 2008).

The analyses presented in this thesis will not attempt to answer why these ZIP codes of high BMP adoption rates differ from the other ZIP codes in the Watershed but will instead attempt to zoom in to these ZIP codes with high instances of BMP adoption events to determine specifically what was happening in those areas of high adoption that could possibly have positively influenced adoption rates. The hypotheses drawn in the analyses on the small scale of these few active ZIP codes can be tested again for validation on the larger scale of the entire watershed. The findings from the analyses in this thesis would be useful to change agencies and their field agents to understand farmer perceptions and the fundamental motivations and influences of successful BMP implementation. The introductory chapter of this thesis gives a brief overview of the Watershed and some additional background information about the previous study that this body of work stems from. The next section of the chapter discusses the role of BMPs in combating and mitigating non-point source pollution from intensive agricultural activities. The chapter concludes with a brief outline of the structure of the thesis.

1.1 BACKGROUND

The South Fork of the Shenandoah River has its head waters in Port Republic, Virginia in southern Rockingham County. It flows northeast, contained by the Blue Ridge to the east and Massanutten Mountain to the west. It is comprised of three tributaries, the North River, the Middle River and the South River (figure 2). The South Fork Shenandoah River Watershed comprises portions of Augusta, Rockingham, Page, and Warren Counties (figure 3).

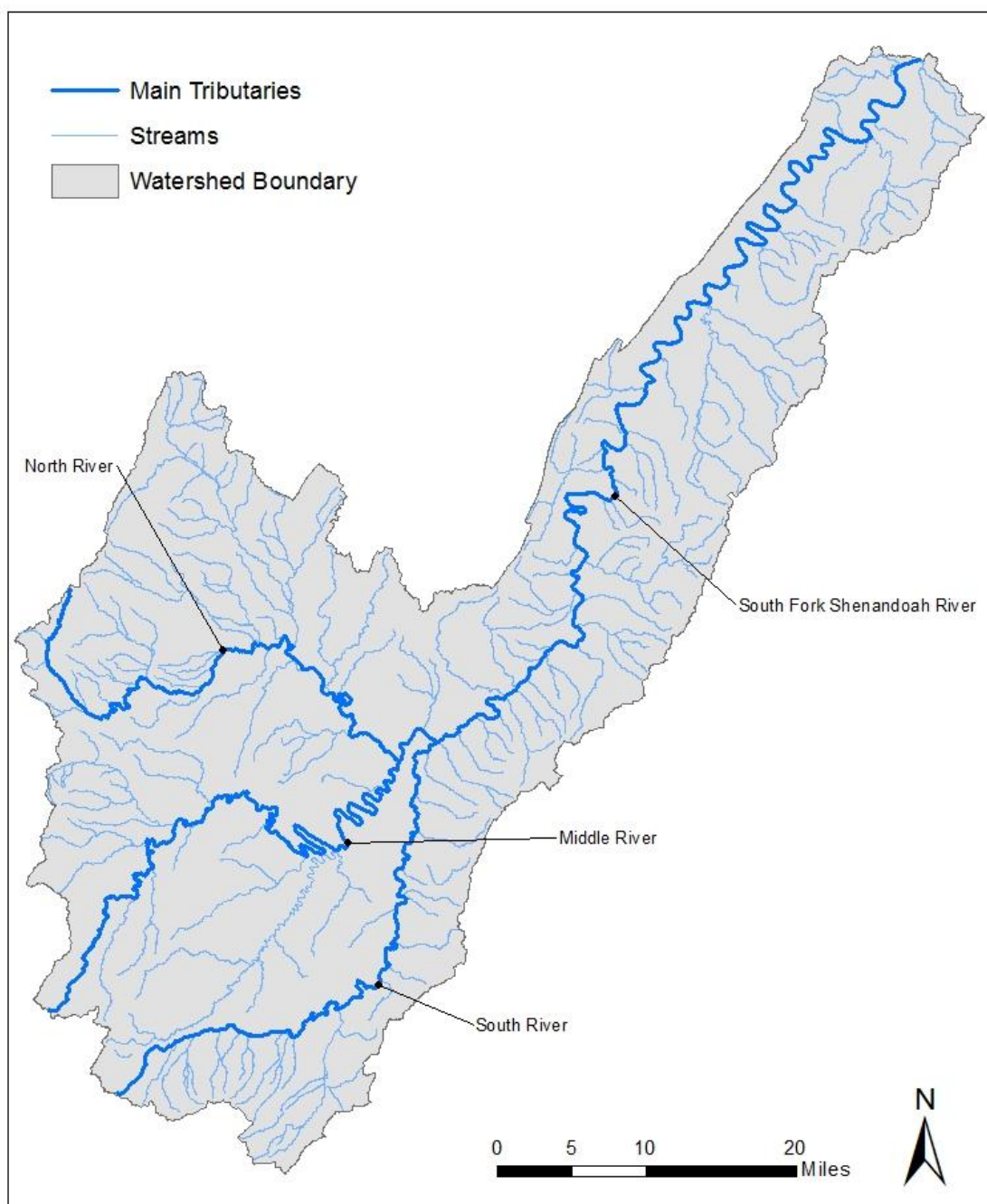


Figure 2. Map showing the tributaries and streams of the Watershed. Source: ESRI

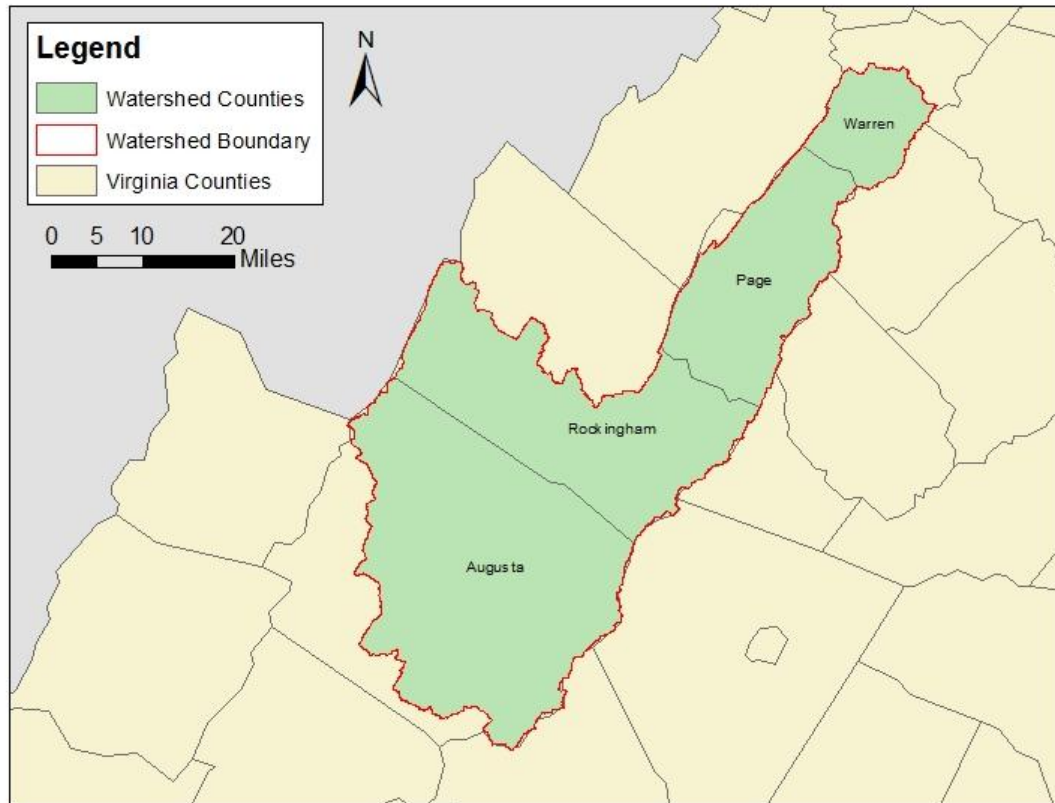


Figure 3. Map showing the boundary and counties of the South Fork Shenandoah River watershed.
Source: ESRI

In 2008, the US Natural Resources Conservation Service funded a Rapid Watershed Assessment (RWA) that assessed the current state of the demographic, biotic, and physical characteristics of the South Fork Shenandoah Watershed (Mizel, Papadakis, Degner, Shepard, & Havinga, 2008). An analysis of agricultural best management practices (BMPs) in the Watershed revealed that several ZIP code locations had higher concentrations of BMP implementation than other ZIP codes (Figure 5).

Noting this obvious spatial pattern and the lack of compelling traditional explanations for why such a pattern may exist, the authors of the RWA recommended further analysis and study of the spatial and temporal characteristics of BMPs in the watershed. This study stems from the recommendations for additional analysis by the RWA.

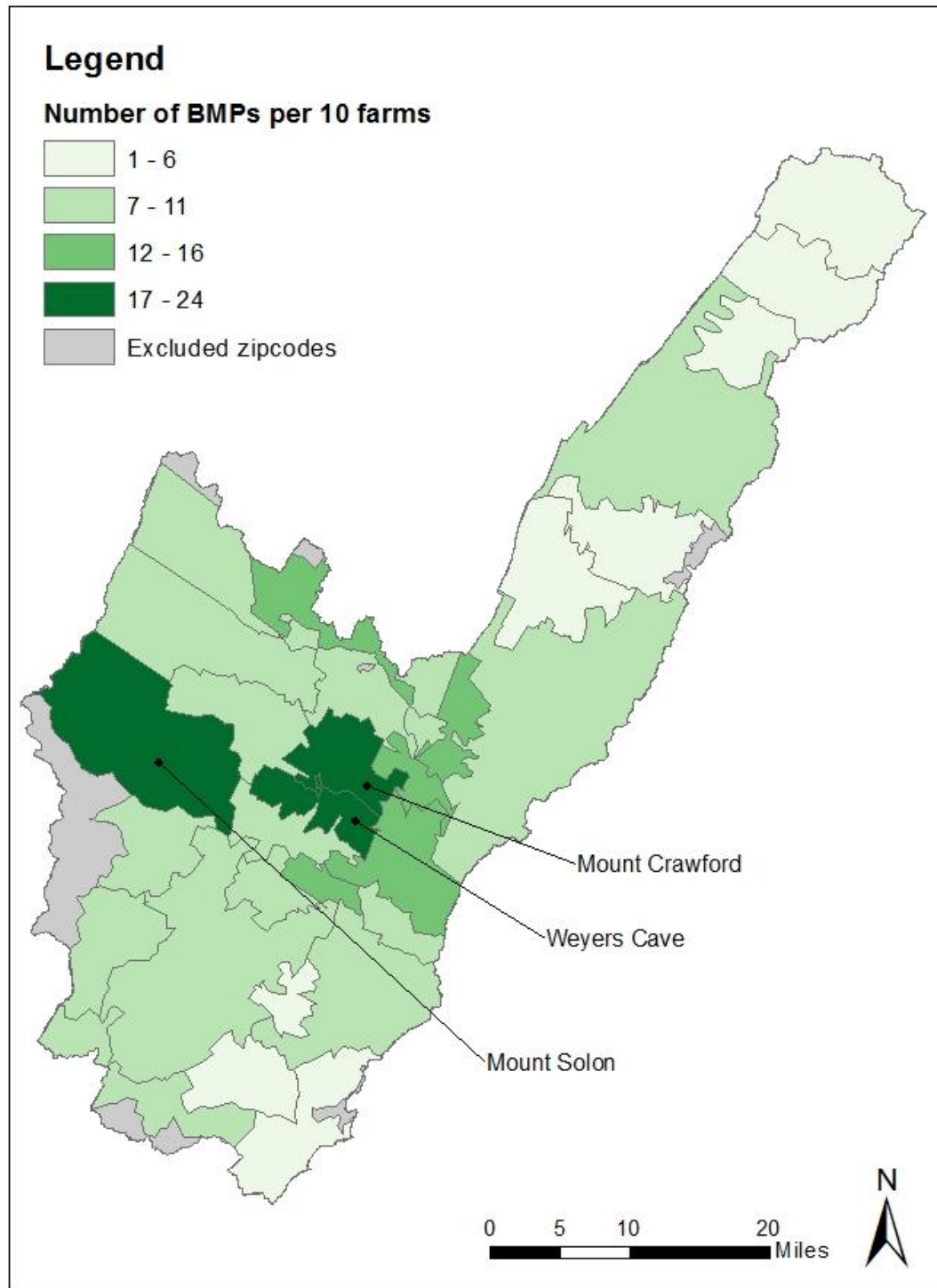


Figure 4. Total Virginia Agricultural Best Management Practice Cost-Share Program VACS BMP Projects in the South Fork Shenandoah Watershed, by ZIP code, 1989-2008. The data presented in this map is normalized to represent the number of BMP adoption events that occurred for every 10 farms within the ZIP code boundaries. Source: (Mizel, Papadakis, Degner, Shepard, & Havinga, 2008, unpublished data) (Virginia Department of Conservation and Recreation, 2008).

1.2 INTENSIVE AGRICULTURAL ACTIVITIES AND THE ROLE OF BMPs

BMPs are designed to prevent and mitigate the negative environmental effects of intensive agricultural activities in a watershed, and the use of BMPs is addressed in Section 319 of the Clean Water Act as a method of reducing pollutant discharge into receiving surface waters (Virginia Agribusiness Council, 2010).

Intensive agricultural activities include confined animal feeding operations, extensive croplands planted in monoculture, and cattle grazing operations. Commonly practiced in North America, these intensive agricultural activities generate by-products that have deleterious effects on surface and ground water quality. Three such byproducts are sediments, pesticides, and fertilizer residues, which come from various causes including but not limited to: streambank erosion from grazing cattle, runoff of pesticides and fertilizer residues in collected stormwater. Fecal *E. Coli* contamination of surface and drinking waters, cattle wading in streams, and poultry litter residues washing and leaching out of soils during rain events are also a major water quality problems.

Stream ecosystems are highly susceptible to negative health impacts caused by contamination from these agricultural stressors. (Yates, Bailey, & Schwindt, 2007). The sedimentation and eutrophication of local surface waters, and resultantly the waters of the Chesapeake Bay, are two of the most damaging consequences of agricultural runoff and contamination of surface waters. Sediment loading of the streams decreases light availability to aquatic flora, inhibiting photosynthesis, killing the flora, and resultantly causing a decrease in the dissolved oxygen in the stream. Sediment from runoff also fills the interstitial spaces of the benthic substrate, causing a loss in essential habitat for macroinvertebrates and other aquatic organisms (Brakebill, Ator, & Schwarz, 2010).

Nutrient runoff from agriculture, such as urea and phosphorus, causes eutrophication of surface waters. This eutrophication produces algal blooms that drastically decrease the dissolved oxygen in the surface waters and resultantly create dead zones in the water column, where only algae and anaerobic organisms can survive. Low dissolved oxygen is considered to be one of the possible causes for massive fish kill events occurring within the Chesapeake Bay watershed (Gilbert, Trice, Michael, & Lane, 2005).

Agricultural BMPs are also known as “best practices” and “conservation practices”. BMPs include both *structural* and (non-structural) *operational* methods to control nonpoint source pollution from agricultural operations. An example of a structural agricultural BMP is livestock exclusion from streambanks (i.e. building fences at a prescribed distance from a stream to prevent cattle and other livestock from entering the stream bed and causing erosion and sedimentation). An example of a non-structural BMP, which relies on changes in a farm’s operational practices, is the use of a nutrient management plan. There is an ever-increasing array of diverse traditional and non-traditional agricultural BMPs that can be used by farmers to control their farms’ pollution into receiving waters. Some of these BMPs require only a small, simple change in farm operations, while other BMPs require a substantial amount of money and time, precious resources to the average farmer.

It is well documented that BMPs are effective at decreasing pollution and sediment inputs into and increasing the overall water quality of receiving waters (Aust, 2010) (Kümmerer, Held, & Pimentel, 2010) (Orzetti, Jones, & Murphy, 2010) (Ruhl & Rybicki, 2010) (Russell, Weller, Jordan, Sigwart, & Sullivan, 2008) (Secchi, et al., 2007) (Yates, Bailey, & Schmindt, 2007). A study on reforested riparian buffers efficacy on

stream health quality in streams of the Chesapeake Bay found data consistent with the hypothesis that forest riparian buffers enhance instream habitat and water quality (Orzetti, Jones, & Murphy, 2010). The study examined habitat, selected water quality variables, and benthic macroinvertebrate community metrics in 30 streams with buffers ranging from less than one year to greater than 50 years of age. They found that streams with reforested riparian buffers showed significant improvements within 5-10 years and improvements nearing conditions of long established buffers within 10-15 years post-restoration (Orzetti, Jones, & Murphy, 2010).

Additionally, a study of sub-basins of the Upper Thames River Watershed in southern Ontario, Canada was conducted to determine whether conservation program implementation was making a significant positive impact on stream health parameters in the watershed (Yates, Bailey, & Schmindt, 2007). They made in situ measurements for physical and chemical measurements, sampled benthic macroinvertebrates and assessed habitat quality. Results from the study indicated that sub-basins with high levels of BMP implementation consistently showed improved stream health significantly more than those sub-basins with relatively low rates of BMP implementation.. It was also found that sub-basins with concentrated BMPs show a much more significant improvement than those with BMPs that are more diffused across the sub-basin. (Yates, Bailey, & Schmindt, 2007)

1.3 SUMMARY, METHODS, AND DATA

The South Fork Shenandoah Watershed provides significant inputs of sediment, microbial contamination and chemical pollution and nutrient loading into the Potomac River, which in turn empties into the impaired and sensitive ecosystem of the Chesapeake Bay. This chapter gave a brief overview of how BMPs can mitigate and prevent these inputs of pollution into the Watershed's surface waters. This chapter summarized the importance of studying the diffusion of BMP adoption and highlighted the important contributions and insights this thesis could potential give to agencies working to promote BMP adoption in the Watershed.

The remainder of this thesis is broken down into four chapters. Chapter two provides a detailed overview and discussion of Innovation Diffusion Theory. Chapter three describes the Commonwealth of Virginia's promotion of BMPs and also provides a detailed literature review of BMPs and the important social connections necessary for BMP adoption. Also discussed are the farmers' attitudes towards BMP promotions and their receptiveness of different BMPs. Chapter three also provides a detailed description of the BMPs adopted in the Watershed and in the subset study area. These data were provided by the Virginia Department of Conservation and Recreation, and are an updated dataset of that used for the Rapid Watershed Assessment of the Watershed (Mizel, Papadakis, Degner, Shepard, & Havinga (2008)). The data represent detailed records of BMP adoption events since the beginning of the Virginia Agricultural Best Management Practice Cost-Share Program (VACS) in 1989. Represented in the data is the information gathered about every individual BMP adoption and implementation through the VACS program from 1989 to 2008. The dataset includes in-depth information about the type of

BMP, the VACS code for the BMP, monetary commitment of the operator, the date of payment, the year of implementation, and the geographic coordinates of each BMP implementation. The presence of spatial information in this dataset allows for an in-depth spatial analysis and the ability to determine how BMPs physically diffused across the space of the watershed. Chapter four provides an in-depth spatial and temporal analysis of the data and also summarizes the essential findings of the thesis. Chapter five describes briefly the limitations of the study and recommends additional research possibilities stemming from the work of this thesis.

2. THE DIFFUSION OF INNOVATION

The beginnings of the study of innovation diffusion were founded in rural sociology; studying agrarian systems and the deep social links within farming communities. One of the most recognized and influential diffusion studies was the study of Ryan and Gross in 1943 that analyzed the diffusion of the planting of hybridized corn (Rogers, 1983). This study occurred during the early twentieth century, a time period of copious industrial agricultural innovation. By the mid to late twentieth century the adoption of agricultural innovations switched gears and dramatically decelerated. Although the adoption of new agricultural techniques and technologies still occurs, it does so at a relatively slow rate compared with innovation adoption in other industrial sectors.

A basic understanding of the diffusion of innovation theory is required in order to comprehend the patterns, social forces, and dynamics at play in the temporal and spatial patterns of the data presented in this study. This chapter provides a comprehensive overview of innovation diffusion theory which includes a summary of the process of innovation adoption, and also provides a description of the different categories of adopters along with their defining characteristics. Also to be discussed are the attributes of innovations that determine their adoptability. It is important to understand that adoption of an innovation by multiple individual adopters in a social system is the origin and impetus of innovation diffusion. The concepts highlighted in this chapter establish a theoretical foundation that will be used to describe the patterns of adoption depicted in the analyses of these data.

2.1 INNOVATION DIFFUSION: A BRIEF DEFINITION

The definition of diffusion of innovation is given by Rogers as, “the process by which an innovation is communicated through certain channels over time among the members of a social system” (Rogers, 1983). There are four main components of diffusion theory highlighted in this definition. The necessary components are an innovation, communication channels, time, and a social system. The successful diffusion of an innovation relies upon the cumulative adoption of that innovation by individuals in a social system over a period of time. Essentially, adoption decisions are the heart of the innovation diffusion paradigm.

2.2 THE INNOVATION ADOPTION DECISION PROCESS

The adoption of an innovation by multiple individual adopters is the driving force behind the diffusion of innovation. If one is to understand the progression of an innovation’s diffusion it is of utmost importance to adequately understand the process leading to the adoption of an innovation. This section describes the innovation adoption diffusion process and the characteristics of the different types of adopters who take part in this process.

The innovation adoption decision process is the sequence of events that an individual goes through from the first introduction to the innovation to the final confirmation of the innovation. The five steps to this process are knowledge, persuasion, decision, implementation, and confirmation. The individual first learns of the innovation

and gains comprehension of its functions.¹ Soon after the individual learns about the innovation he or she forms a favorable or opposing opinion about the innovation. The individual's opinion leads him or her to adopt or reject the innovation. If the innovation is accepted by the individual he or she may decide to implement the innovation. Depending on the success of the implementation and on the feedback of others the individual will then make a decision to continue or discontinue the adopted practice. Also in the confirmation stage a person who previously rejected the innovation may decide to adopt and implement when influenced by others' success with the innovation (Rogers, 1983).

While the model of innovation adoption decision-making is useful for explaining the process, it is the reaction of the individual adopters to this process that determine the pattern and extent of innovation diffusion.

Individual adopters react differently to the innovation adoption decision process based on the adopters' degrees of *innovativeness*, an individual's capability to think and act independently from others in their social system. Innovativeness is also described by Rogers (1983) as being the degree to which an individual is relatively earlier in adopting an innovation than others in the community. In 1963, using logistics s-shaped curve to show the bell-shaped curve of the adoption participation phenomenon, Rogers categorized the different adopter types into five distinct categories based on the adopters' level of innovativeness. These five categories, listed in the order from the most to the least innovative, are: the innovators, the early adopters, the early majority, the late majority, and the laggards (Rogers, 1983), see figure 5.

¹ An individual can gain knowledge about an innovation through various channels of communication.

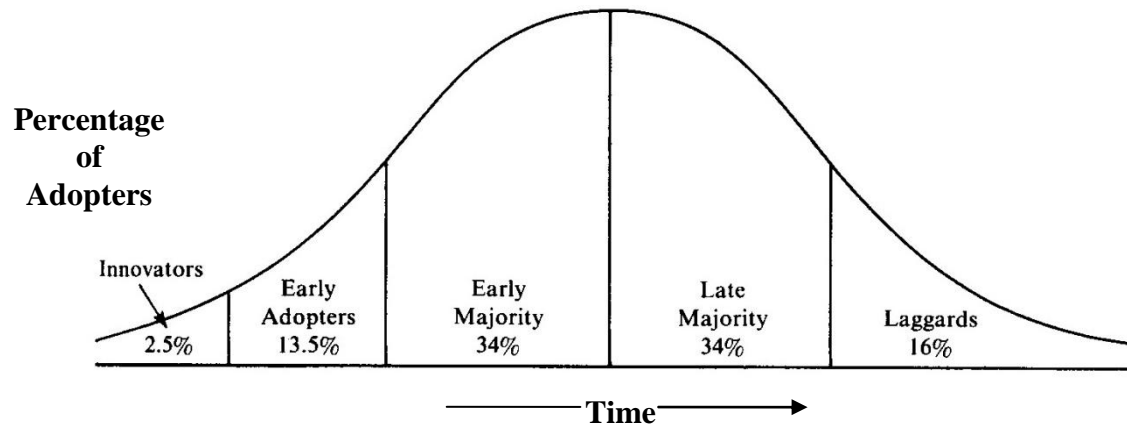


Figure 5. Categorization of adopters based on innovativeness. Source: (Rogers, 1983, p. 247)

As seen in Figure 5, the innovators are the first 2.5% of the community who initially adopt an innovation. Innovators are described by Rogers (1983) as being “gatekeepers” who bring innovations into the community from outside the social system’s boundaries. Innovators are venturesome risk takers and often experiment with innovations. Their experimentation of new technologies and techniques is possible because they have substantial monetary resources able to absorb any negative financial consequences of an innovation’s possible failure. They also are able to comprehend complex technical information. Innovators often have far-reaching and geographically dispersed social connections with other innovators, bridging outside of their locality’s social network. The qualities of the Innovator are often heterophilous to the qualities of the majority of members in the local community. It is because of these differences, and the innovators’ often dismissive attitude toward social norms, that they may not be well respected by or socially connected to most of the community members.

The early adopters comprise the 13.5% of the community who adopt the innovation after the Innovators, see Figure 5. The early adopters have a high degree of innovativeness but are less rash and more homophilous to the rest of the community than

the innovators. Early adopters are the first among the traditionally minded community members to adopt an innovation. These adopters are usually well respected in the local social system and have the largest degree of opinion leadership than any other type of adopter; often serving as role models to the community regarding successful and judicious use of innovations. Early adopters have an extensive social connectedness with members of the local community. When early adopters adopt and successfully implement an innovation, they also decrease uncertainty and skepticism about that innovation. This reduction in uncertainty about the innovation enables the other more skeptical and wary types of adopters to adopt.

The adopters of the early majority are the first to adopt an innovation after the successful implementation by the early adopter. The early majority category of adopters is described by Rogers (1983) as being followers with deliberate willingness to adopt, who seldom lead. These adopters proceed with cautious interest about the innovation, but after the innovation has been proven successful and beneficial they readily adopt it. The early majority acts as the linkage between the earliest adopters and the relatively late adopters.

The adopters of the late majority are unwilling and very skeptical about new ideas and techniques. They will adopt an innovation only after the average number of members has adopted it, usually due to an increase in social pressure from peers in the community.

The last of the adopter types to adopt an innovation are the laggards. These adopters are very traditional, socially isolated, and often have few financial resources. The laggards' point of reference for techniques and technology stems from what worked in the past for previous generations. Often a laggard's adoption of an innovation occurs at

a point in the diffusion process where that particular innovation has already been superseded by an even newer innovation and is being implemented by the innovators.

In summary, the relatively high degree of innovativeness inherent in innovators and early adopters, and the even moderate degree of innovativeness in the early majority allows them to be grouped together as leaders in the diffusion of innovation process, while the subsequently low degree of innovativeness of the other adopter categories of the late majority, laggards, and non-adopters allows these adopter types to be grouped together as imitators (Rogers, 1983).

To understand the unique social dynamics at play in the diffusion of individual innovations, it is most important to study the leading categories of adopters who demonstrate truly innovative behavior. The mean of the bell-shaped curve showing the different categories of adopters is the dividing line between the *innovators* and the *imitators* (Koebel, Papadakis, Hudson, & Cavell, 2003) (Rogers, 1983). This point in the bell-shaped curve is known as the inflection point and it represents the point in the diffusion process where the rate of adoption begins to decelerate because the community is becoming saturated with this innovation. All adoption activities that occurred before the inflection point (the innovators, early adopters, and early majority) are considered truly innovative while all adoption activities occurring after the inflection point (the late majority and laggards) are attributed to the “competitive bandwagon effect” (Koebel, Papadakis, Hudson, & Cavell, 2003). This bandwagon effect is also addressed in 1979 by Willard W. Cochrane who describes this effect as an agricultural “technology treadmill”, where a farm must adopt a technology to remain competitive in the market or face being taken over by more productive farms in the community (Fuglie & Kascak, 2001).

2.3 INNOVATION PROPERTIES

An innovation is an idea, practice, or object *that is perceived as new by an individual*. Technologies are often referred to as innovations and are considered synonymous by some. However, technology is defined as a design for instrumental action that reduces the uncertainty in the cause-effect relationships involved in achieving a desired outcome. Some innovations can be technological or physical in nature while other innovations can revolve around change in thought.

There are characteristics of innovations that affect their rates of adoption. These characteristics are relative advantage, compatibility, complexity, trialability, and observability (Rogers, 1983). Relative advantage identifies to what degree an innovation is perceived as better than the preceding idea. Compatibility identifies to what degree an innovation is perceived as being consistent with the values and needs of the potential adopters. Complexity identifies to what degree an innovation is perceived as difficult to understand and facilitate. An innovation with a high degree of complexity requires adopters to develop new skill sets, thus this added requirement can decrease the rate of adoption of a complex innovation. Trialability identifies to what degree an innovation may be tested or experimented with on a short-term trial basis. Innovations with high degrees of trialability are conducive to high rates of adoption. Observability identifies to what degree the results of an innovation are visible to others. All of the above properties of innovations, excluding complexity, have positive correlations with adoption rate; meaning that as the degree of the properties increase so also do the rates of adoption increase. This correlation is negative between the innovation's degree of complexity and

the resultant rate of adoption. As the innovation's degree of complexity increases, the adoption rate of the innovation decreases.

To summarize, innovations are ideas and practices that are perceived as new by individual potential adopters, and the properties and attributes of an innovation directly influence the innovation's adoption potential. Each unique innovation will have varying levels of all four innovation attributes: relative advantage, compatibility, complexity, trialability, and observability. It is important to realize the strong linkage between the social forces at play and the properties of innovations. Each unique innovation will be accepted into individual social systems with varying rates of success based not solely upon the unique characteristic of the innovation but also upon the unique and defining characteristics of the individual communities.

2.4 THE SOCIAL SYSTEM, COMMUNICATION CHANNELS, & DIFFUSION

When studying innovation diffusion within a community, the physical spatial dimension and the social dimensions are considered. The spatial dimension of innovation diffusion is discussed in section 2.5 of this chapter (p. 23). There are four main analytical social dimensions that are considered in innovation diffusion: Interpersonal relations, socio-cultural factors, socio-economic factors and political-institutional factors (Ciciotti, Alderman, & Thwaites, 1990, pp. 45-53). Interpersonal relations entail the social connections established between members of a social system as well as the hierarchical influences present in those social connects; whether the connections are cosmopolitan or local (Rogers, 1983). Socio-cultural factors deal with the cultural and social norms and traditional practices present in the community. Cultural norms and traditions can be both

a strong barrier and advocating force for innovation adoption. Socio-economic factors include a person's social connectedness, financial resources, and education. The social connection and influence is the pathway for knowledge exchange within a community and is central to the successful dispersal of knowledge about an innovation within a social system. Therefore a person's social status defines their ability to influence others or be influenced by others. A person's level of education can make them receptive to new ideas and increase their innovativeness. In terms of financial resources, a person's wealth is very decisive of their ability to take risks on an experimental innovation or even invest in widely practiced innovation that requires a substantial capital investment. Often a person's affluence and social status go hand in hand. Political- institutional factors are the pressures, influence, or control a governmental or social authority has on a community. The initiation of an innovation adoption campaign is always started by a change agency, whether that change agency is governmental or grassroots based doesn't matter, it is still a political-institutionally initiated effort. Change agencies widely use all communication channels open to them to educate the community about innovations.

There is a prominent rule of innovation diffusion known as the *diffusion effect*, which creates a positive correlation between the amount of knowledge given about and social influence put upon an individual about an innovation and the person's likelihood to adopt that innovation. Rogers (1983) emphasized the importance of the diffusion effect on adopters by insisting, "Until an individual has a certain minimum level of information and peer influence from his or her system's environment, he or she is unlikely to adopt." Rogers goes on to discuss the presence of a threshold of awareness and peer influence that tips the scales and increases the likelihood of adoption, usually occurring after the

opinion leaders in the community have adopted the innovation and continuing gradually until the innovation has been accepted by the entire community (Rogers, 1983). The review of literature conducted by Koebel, Papadakis, Hudson, & Cavell (2003) found that the diffusion effect has been cited in many innovation diffusion studies as the mechanism for contagious spread of a specific innovation. One such citation was used from a study conducted by Jaffee and Stavins (1995), “If knowledge of existence and profitability are increasing functions of prevalence of use of a technology then use of that technology can be expected to spread like a disease: the probability that a non-user will adopt in any time period will be an increasing function of the fraction of the population that has already adopted” (Koebel, Papadakis, Hudson, & Cavell, 2003, p. 2).

Information and interpersonal influence about an innovation move through communication channels. The two main types of communication channels involved in innovation diffusion are mass media and interpersonal channels. Mass media channels transmit messages through a mass medium such as radio, television, magazine or newspaper articles. This allows for a wider broadcasting of information from a single source to a large audience (Reddy & Sudharani, 2007).

Interpersonal channels facilitate the exchange of information from one person to one or more other persons via reciprocal discussion and interaction. One important means of interpersonal communication in innovation diffusion is the influence of a change agent. A ***change agent*** is an individual who influences clients’ decisions in a direction deemed beneficial by the ***change agency***, the organization or authority which the change agent is a member or employee of. Governmental agencies such as the United States Environmental Protection Agency, the United States Department of Agriculture, the

Center for Disease Control, and even local governmental agencies such as state departments who manage environmental and/or natural resource managements are fulfill the role of change agencies when seeking to implement policies that require changes in prominent modes of operation or behavior.

Change agents are the professionals, usually university and technically educated, who work for change agencies. Examples of change agents include enforcement officers from state departments of environmental quality and doctors from health departments. Change agents use the community's most influential persons to gain social acceptance of a change or innovation. This is done through use of the power of *opinion leadership*. Opinion leadership is very important for any change or innovation to be accepted by the social system. An opinion leader is someone who has respect from the community and social network by maintaining technical competence, has a high degree of social accessibility, and also conforms to social norms (Rogers, 1983). An opinion leader acts as a trend setter for their local social system, directly and indirectly influencing others in the community through their implementation of an innovation and/or their promotion of an innovation.

The transfer of new ideas and concepts occur with greatest success when the two individuals involved are *homophilous*; alike intellectually and share similar socio-economic standing. The interpersonal communication channels between change agents and the majority of the potential adopters in a community, especially those adopters of the late majority and laggards, are blocked by the social factors. The change agents may be able to easily communicate with the innovative adopters because they are socially and intellectually homophilous to one another. However, often change agents must

communicate with isolated and often skeptical potential adopters who are *heterophilous*, differing intellectually and socio-economically, to the change agent. The heterophilous nature of this relationship can create a barrier to communication, thus decreasing the successful dissemination of information regarding an innovation. To overcome this obstacle change agencies will hire aides, who are more homophilous to the potential adopters, to contact clients in order to influence their innovation decisions. These aides are technically trained about the innovation but will share many socio-cultural views and also share a similar socio-economic status to that of the potential adopters and thus will have more success exchanging information and influencing that particular portion of the population (Rogers, 1983). Examples of change aides might include field technicians from a state department of environmental quality (instead of enforcement officers) or nurses from health departments (instead of doctors).

The phenomenon of homophilous and heterophilous social statuses between the change agent and the potential adopter and their resultant impacts on communication channels is especially prevalent in studies of agricultural and conservation innovation adoption (Clearfield & Osgood, 1986) (Fuglie & Kascak, 2001) (Greiner, Patterson, & Miller, 2009) (Kim, Gillespie, & Paudel, 2005) (Rogers, 1983).

In summary, the spread of an innovation is the result of cumulative, individual adoption decisions about that innovation. An individual's adoption decision is determined by many complex yet interrelated factors including: the potential adopter's personal socio-economic status, their degree of interpersonal connectedness to other members of the community, as well as the various socio-cultural and political- institutional factors at play in the community. A person's adoption decision is also greatly influenced by their

knowledge and awareness about the innovation, the properties of the innovation, and the intensity of peer influence regarding the innovation. Individual adoption decisions about an innovation form a network of accumulative adoption decisions which branches out to interconnect multiple geographically scattered communities of adopters. Truly the accumulation of individual adopter decisions and their resultant influences are the driving forces of the spatial diffusion of innovations.

2.5 PATTERNS OF SPATIAL DIFFUSION

Simply put, spatial diffusion is the spread of a phenomenon over geographic space (Morrill, Gaile, & Thrall, 1988). A phenomenon is born and moves from its place of origin to other locations. There are three main types of spatial diffusion that are considered when studying spreading phenomenon. These three types are contagious expansion, hierarchical expansion, and relocation diffusion. The graphics presented below in figure 15, visually explain these three spatial diffusion types.

In the study of infectious disease dynamics, the contagious expansion model of diffusion is widely used. This type of diffusion is based on the fact that mechanisms by which “diseases” are spread involve exposure via proximity and subsequent infection as the disease agent is spread from one individual to the next. Hence, the originally “infected” individual “infects” others in close proximity. This pattern continues from infected person to susceptible person until the disease has spread entirely across the region (figure 6a). The successful use of this model in modeling the spread of disease has resulted in a long history of epidemiology and its use of spatial diffusion and cartography to successfully predict, control, and prepare for epidemics (Cromley &

McLafferty, 2002) (Haggett, 2000) (Koch, 2005) (Lawson, 2006) (Morrill, Gaile, & Thrall, 1988) (Rogers, 1983).

The model of hierarchical expansion diffusion is also used in the study of disease spread. One of the most well-known uses of this model was the use of hierarchical diffusion in the study of HIV/AIDS spread in the United States (Haggett, 2000) (Koch, 2005). In the example of HIV/AIDS diffusion, spread of the virus begins in a large city via contagious expansion dynamics. However, the disease then “jumps” to other large cities in the urban hierarchy via travel of carriers to those cities. Expansion of the epidemic then occurs within the city via contagious expansion. In this way, the disease “leapfrogs” from city to city, eventually spreading to smaller towns, and eventually into rural areas (figure 6b). Hierarchical expansion diffusion can also occur in a social hierarchy, where an individual of influence adopts an innovation and persuades other influential persons to adopt who in turn convince people in a lower level of the social hierarchy to adopt the innovation. Examples of this kind of hierarchical expansion diffusion are: fashion trends, adoption of technological innovations, and adoption of agricultural technologies and machines.

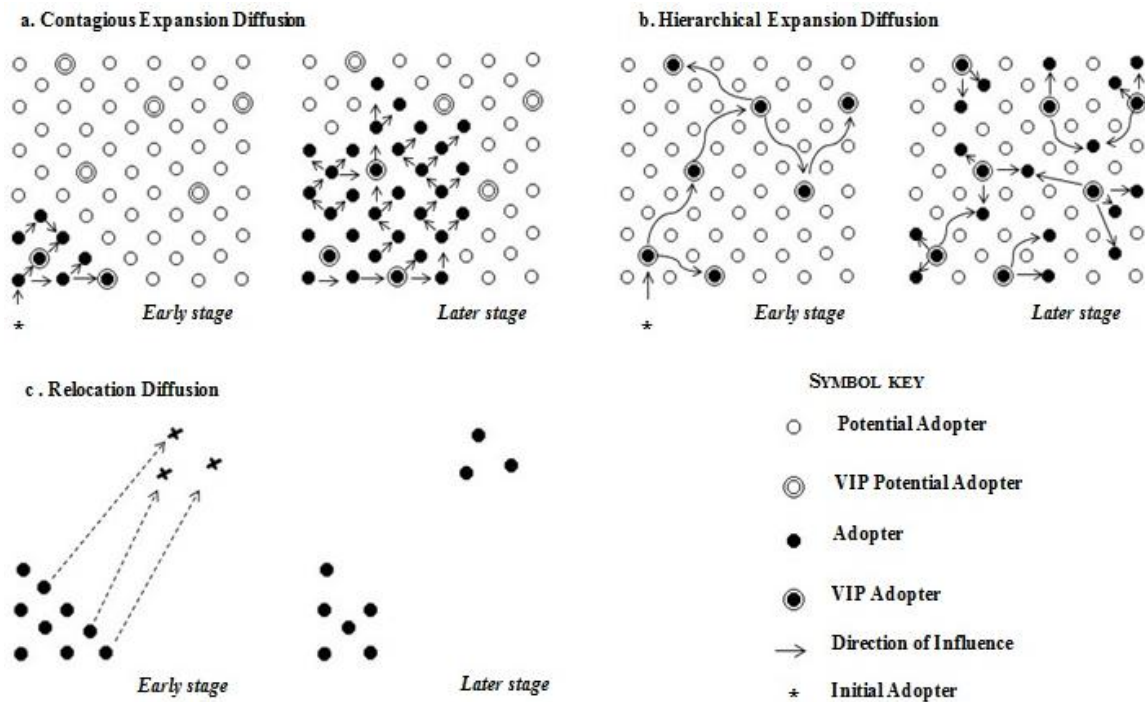


Figure 6. Three types of Spatial Diffusion. Adapted from source: (Morrill, Gaile, & Thrall, 1988)

The third type of spatial diffusion is relocation diffusion, see figure 6c. This is most often related with migration. Migration is the movement of people, organisms, and animate and inanimate objects from one place to another. Migration is often the result of displacement, immigration and emigration from one physical location to another. A few common examples of this kind of diffusion are: the yearly migration of birds and other animals, the mass exodus of people fleeing a war-torn country, and the displacement and resultant movement of animals because of habitat loss or change.

The innovation diffusion theory is based on a contagion model. This means that much like a person infected with a contagious virus, such as the common cold, will possibly infect those who come into close contact with them, so also will an innovation adopter influence others in their proximity to adopt the innovation. A person's proximity

to others is not only in physical distance but also in social connectedness, the social proximity. Gabriel Tarde, considered one of the forefathers of innovation diffusion theory, wrote in his book entitled “Laws of Imitation”, that the purpose of his study was “to learn why, given one hundred different innovations conceived at the same time, ten will spread abroad while ninety will be forgotten (Tarde, 1903).”

Social interaction and imitation of peers are strong forces that often dictate our behaviors and choices. In the case of BMP promotion, both mass media and interpersonal communication channels are used. Local Soil and Water Conservation Districts (SWCD), the change agency in the BMP diffusion scenario, use field officers as change agents to promote conservation practices and provide technical assistance to farmers who wish to implement BMP strategies and install conservation structures. Often aides will work with innovative farmers or farmers who are opinion leaders in the community to enact change and gain acceptance of BMPs in the farming community. One opinion leader who adopts and promotes a BMP will influence and convince other opinion leaders in the community to adopt the BMP on their properties. The multiple opinion leaders will then directly and indirectly influence other farmers in the community, who may have different socio-economic status than the opinion leading farmer to adopt the BMP on their farm. Those farmers who have implemented BMPs successfully will knowingly and unknowingly influence other farmers in a certain proximity to them. The diffusion pattern from this BMP adoption scenario is suggestive of hierarchical expansion diffusion.

2.6 IMPLICATIONS OF THE LITERATURE FOR AGRICULTURAL BMP ADOPTION AND DIFFUSION

Agricultural BMPs are clearly innovations even though they represent techniques rather than technologies. The four necessary components of innovation diffusion are present in the BMP diffusion scenario: there is an innovation, there are communication channels, there are complex social systems and there is time. As stated before, the spread of innovation is the result of cumulative, individual adoption decisions about the suitability of an innovation for the individual adopter.

An individual's adoption decision about an innovation is influenced by his or her knowledge and awareness of the innovation as well as the properties of the innovation such as relative advantage, compatibility, complexity, trialability, and observability. The different BMPs occurring in the study area have varying degrees of these properties, making some BMPs good candidates for adoption and others not. Along with social interaction and acceptance, a BMP's success relies on the characteristics listed above (refer to Chapter 3, p. 47 for more in-depth information about these characteristics' influence on the different BMPs' adoptability). For example, an annual grain cover crop is much more likely to be adopted than a buffer installation, because it has a good relative advantage, trialability, and observability and it is not complex. A buffer has little advantage for the farmer, is not trialable and it has a moderate degree of complexity. Installing a buffer BMP usually requires the installation of alternative watering systems for livestock. These two closely linked BMPs require a substantial capital investment that is not feasible for most owner/operators of small farms. Some BMPs, such as nutrient management plans often require the operator of the farm to learn additional, often complex, information about chemistry and application methods. The additional level of

complexity inherent in the nutrient management plans has a negative impact on the adoption rates of this BMP.

Characteristics of the social system influence individual adoption decisions about agricultural BMPs. These societal characteristics include the socio-cultural, socio-economic, political-institutional attributes of the change agent and the potential adopters in the community. Communication channels, especially interpersonal communication, are most fruitful when the change agent and potential adopters of the community share similar levels of these social attributes. Also of importance is the degree to which an innovation is compatible with these social factors, particularly the socio-cultural factors.

As discussed previously in this chapter, it is understood in literature that the spatial diffusion of innovations is a function of the effects of both contagion and hierarchical expansion models. The effects of these models, especially those effects of contagious expansion, highlight the importance of proximity of adoption events in this analysis. Defining the specific type of spatial diffusion occurring in the watershed critically relies on the physical spatial configurations of BMP adoption events displayed in the data. These physical configurations are reliant on the proximity of adopting farmers to those farmers who previously adopted the BMP. A comparison of the BMP adoption events' dispersal in the study area and the spatial diffusion configurations present in the contagion and hierarchical diffusion model is made possible by determining the presence of BMP adoption events clustering and visualizing the spatial dispersion of those events in the study area.

The foundational information provided in this chapter and the following chapters' additional comprehensive overview of the characteristics and properties of the individual

BMPs involved in this study area will help to support conjecture about the forces driving spatial diffusions of BMP adoption event diffusion in this particular watershed and especially in the areas of this watershed with high levels of adoption activities.

3. DIFFUSION AND CHARACTERISTICS OF BMPS

This chapter seeks to describe in detail the pivotal properties of the individual BMPs adopted in the watershed in order to explain why some BMPs are actively adopted and why other BMPs are infrequently adopted. Two additional properties of BMPs that define their adoptability are the nature of the BMP's implementation, whether it is structural or operational, and the affordability of the BMP. All of these properties and characteristics of each individual BMP category will be discussed in this chapter.

As was discussed in Chapter 1, BMPs increase stream health by decreasing nutrient and sediment inputs into streams and, in the case of riparian buffers and livestock exclusion, halt stream bank erosion. Widespread participation in agricultural BMP implementation is crucial for the successful abatement of pollution from agricultural activities flowing into surface waters of the Potomac River watershed and ultimately the impaired Chesapeake Bay. However, the implementation of agricultural BMPs on farms is strictly voluntary and is not imposed on farmers through command and control regulation. It is because of the voluntary nature of BMP implementation on farms that there is a vested effort on the part of state and local organizations such as the DCR and SWCDs to incentivize and promote the use of BMPs on farms. This chapter will provide a historical overview of BMP promotion in the Commonwealth of Virginia. Also discussed in this chapter are the spatial diffusion of BMP adoption events in the South Fork Shenandoah River watershed and a brief explanation of the "hotspots" of BMP adoption activities, which are analyzed in greater depth in Chapter 4. The chapter will

conclude with a summary and discussion of the possible connection between the individual BMP properties and the “hotspot” of BMP adoption activity in the watershed.

3.1 HISTORY OF VIRGINIA’S PROMOTION OF BMPs

The Commonwealth of Virginia promotes the implementation of agricultural BMPs through the encouragement of voluntary BMP implementation and through the Virginia Agricultural Best Management Practice Cost-Share Program (VACS). VACS is administered by the Virginia Department of Conservation and Recreation (DCR) through Virginia’s 47 local Soil and Water Conservation Districts (SWCD)(Virginia Department of Conservation and Recreation, 2011). VACS works to incentivize implementation of BMPs by offering financial and technical assistance to land-owners and farm operators who voluntarily agree to implement or construct selected BMPs. VACS began in 1984 and offered funding for only a few eligible BMPs. Through the years VACS has expanded to include numerous eligible BMPs into the program.

VACS works closely with the Chesapeake Bay Program to assist with program goals and initiatives. Especially important to the VACS program was the signing of the 1987 Chesapeake Bay Agreement, which committed the U.S. Environmental Protection Agency (EPA) to work with Pennsylvania, the District of Columbia, Maryland, and Virginia to reduce nutrient inputs into the Chesapeake Bay by 40%. This agreement, along with the Chesapeake 2000 agreement signed by Virginia Governor Gilmore, helped to boost the VACS’ funding and resources. The VACS program also gained heightened priority when the Chesapeake Bay was placed on the federal list of impaired waters.

The placement of the Chesapeake Bay onto the federal list of impaired waters obligated Virginia to take more aggressive action against nutrient loading and to become compliant with Section 319 of the Clean Water Act which addressed nonpoint-source pollution. This brought about the implementation of Total Maximum Daily Loads (TMDL) allocations on Virginia state waters. The EPA required each state to develop, by 2010, a Watershed Implementation Plan (WIP) to meet TMDL allocations. EPA requires that all practices necessary to achieve TMDL allocations be implemented by 2025 (Virginia Agribusiness Council, 2010).

The focus given to TMDL allocations forced the DCR and local SWCDs to focus and give preference to BMPs that are the most cost effective and yield the most nutrient and sediment reductions. In 2004, the book entitled *Cost-Effective Strategies for the Bay* was published by the Chesapeake Bay Commission (CBC). The book provided an analysis of BMPs that were the most cost-effective, producing the best results for the least cost to taxpayers. The CBC listed the following BMPs as the most cost effective: diet and feed adjustments, traditional nutrient management, enhanced nutrient management, conservation tillage, and cover crops. Using this book as a guideline, the DCR selected BMPs from the VACS program that were highlighted in the CBC's book and gave them priority over all other BMPs in the program.

These strategic BMPs were listed by DCR as "priority practices" and were from then on given the most resources, funding, and promotion by SWCD agents (Virginia Department of Conservation and Recreation, 2011). The VACS BMPs that best aligned with those recommended by the CBC were: "Nutrient Management Plan Writing and Implementation (NM-1, & NM-2), side dressing and split nutrient applications, (NM-3,

NM-3B, NM-4), Cover Crop practices, (SL-8, SL-8B and SL-8H, WQ-4), along with Permanent Vegetative Cover on Cropland (SL-1) and Continuous No-till Systems (SL-15A and SL-15B)... livestock exclusion practices (SL-6, WP-2 & LE-2 & SL-7 (in the Bay Only) and CCI-SE1) and riparian buffer practices (FR-3, WQ-1, CCIHRB-1 and CCI-FRB-1),”(Virginia Department of Conservation and Recreation, 2011).

The majority of funding for VACS comes from the Virginia Water Quality Improvement Fund (WQIF) (Virginia Department of Conservation and Recreation, 2011). In 2008, the Commonwealth of Virginia developed the Virginia Natural Resources Commitment Fund (VNRCF), a sub-fund of WQIF dedicated to funding the implementation of agricultural BMPs that abate nonpoint-source pollution. Funding for VACS also comes from federal and state grants, such as the Chesapeake Bay Implementation Grant that is administered by the DCR. The Natural Resource Conservation Service, part of the USDA, provides 75% of the funding for the BMPs that are part of the Conservation Reserve Enhancement Program (CREP). The remaining 25% of the funding for CREP BMPs is provided through WQIF.

Each individual SWCD annually receives allocated funds for implementation of VACS BMPs in their sub-watersheds. These allocations are based upon budgeting agreements made between all 47 individual SWCDs. The total annual funding for VACS varies each fiscal year based upon budgetary decisions made by the Commonwealth of Virginia General Assembly about WQIF and various grants. Funding is a major concern for SWCDs and to farmers, as the changes in funding from year to year can be volatile. For example, from 1997 to 2000 there was an increase in funding from about 1 million in 2007 to over 13 million in 2000, equating to a total increase of nearly 12 million dollars.

In line with the volatile nature of the funding, from 2000 to 2002 there was a decrease of 12.4 million dollars in funding, see Figure 7.

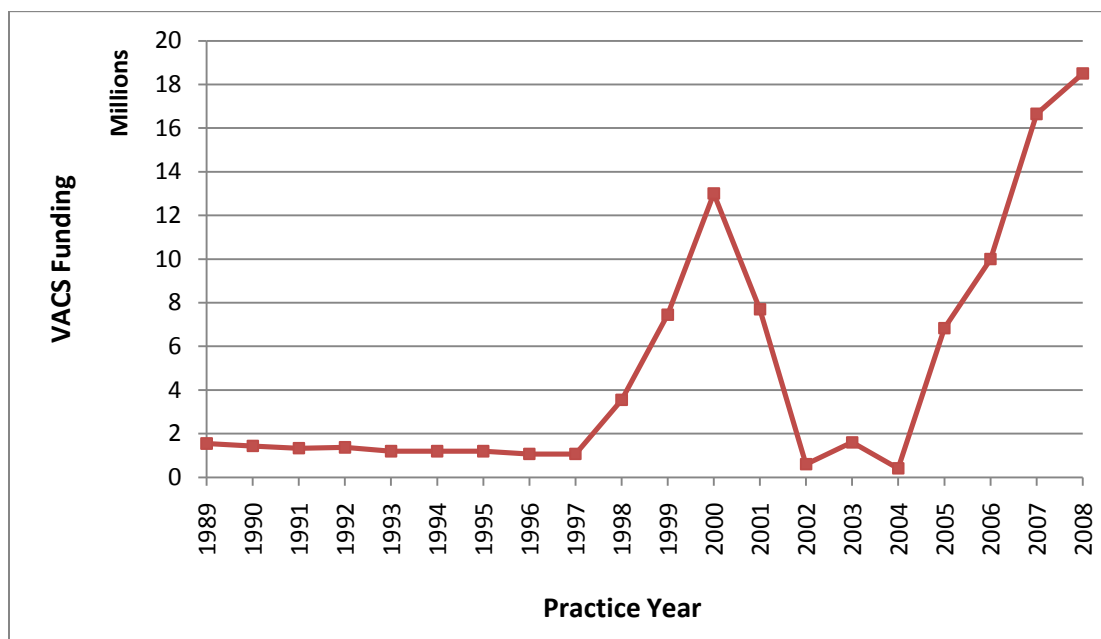


Figure 7. Graph of annual funding for VACS, 1989-2008. Source: DCR, unpublished data.

The majority of the annual funds dispersed to local SWCDs are dedicated to incentivize the aforementioned priority practices. Up to 80% of the funds available to the SWCDs for the VACS program are dedicated solely to priority practices, leaving only 20% of the remaining funds for other BMPs cost-share opportunities. Given Virginia's emphasis on priority practices, local SWCD are advised and urged by the DCR to actively promote "priority practices" to their districts. The interaction between SWCD field agents and the community can be thought of in the terms of communication channels in the theory of innovation diffusion. The SWCD uses both mass-media communication channels and interpersonal communication channels to inform the community about BMPs and encourage their implementation. Mass media communication methods used by SWCDs include videos, brochures, flyers, and monthly

and annual newsletters. Interpersonal communication methods used by SWCDs include group presentations, pasture walks, workshops, and individual consultation visits made by field agents and conservation technicians. SWCD agents and technicians work to inform farmers about BMP implementation opportunities as well as provide hands on technical assistance to farmers during the planning and installation stages of the BMP implementation. NRCS employees such as district conservationists and soil conservationists work closely with local SWCD and farmers to provide additional technical assistance for BMP implementations. The NRCS is especially involved in facilitating the implementation of CREP BMPs, as the majority of funding and support for CREP is made possible through the Farm Service Agency (FSA) and NRCS.

3.2 BMPs IN THE SOUTH FORK SHENANDOAH RIVER WATERSHED

The VACS BMPs implemented in the Watershed are diverse, comprising a total of 36 different BMPs, which are consolidated into nine BMP categories, see Table 1. A number of the individual BMPs have particularly high numbers of adoption events in the watershed during the twenty year period from 1989 to 2008. These noteworthy BMPs are: CP-22, CRFR-3, SL-8B, SL-8H, WQ-4, SL-6, WP-2, NM-3, FR-1, SL-1, WP-4, and WP-4C.

The buffer BMPs that showed high levels of participation were both CREP riparian forest buffer BMPs, CP-22 with 79 adoption events and CRFR-3 with 81 adoption events. The only major difference between these two CREP BMPs is the difference in payment rates to farms because of the “rental only” status of CP-22, meaning that the Commonwealth of Virginia “rents” the designated portion of property

Table 1. Description and Frequency of BMPs in the South Fork Shenandoah Watershed.

VACS Code	Structural or Operational	BMP Type	Quantity	Description of BMP
CP-21	Structural	Buffer	*	CREP Filter Strip (Rental only)
CP-22	Structural	Buffer	79	CREP Riparian Forest Buffer (Rental only)
CP-22B	Structural	Buffer	*	CREP Riparian Forest Buffer (Rental only)
CP-29	Structural	Buffer	*	CREP Wildlife Habitat Buffer (Rental only)
CRFR-3	Structural	Buffer	81	CREP Riparian Forest Buffer
CRLF-1	Structural	Buffer	*	CREP Buffer Length Recording
FR-3	Structural	Buffer	8	Woodland Buffer Filter Area
FR-4	Structural	Buffer	*	Woodland Erosion Stabilization
WQ-1	Structural	Buffer	*	Grass Filter Strips
WQ-6B	Structural	Buffer	*	Wetland Restoration
SL-8B	Operational	Cover Crop	1012	Small Grain Cover Crop for Nutrient Management
SL-8H	Operational	Cover Crop	308	Harvestable Cover Crop
WQ-4	Operational	Cover Crop	57	Legume Cover Crop
SL-3	Operational	Cropland Drainage	38	Stripcropping Systems
WP-3	Structural	Cropland Drainage	12	Sod Waterway
SL-6	Structural	Livestock Exclusion	297	Grazing Land Protection
SL-6B	Structural	Livestock Exclusion	6	Alternative Water System
WP-2	Structural	Livestock Exclusion	48	Stream Protection
NM-1	Operational	Nutrient Management	40	3 Year Contract for Nutrient Management Plan
NM-3	Operational	Nutrient Management	53	Sidedress Application of Nitrogen on Corn
NM-3B	Operational	Nutrient Management	16	Organic Fertilization to corn w/ pre-sidedress Nitrate Test
NM-4	Operational	Nutrient Management	8	Late Winter Split Application of Nitrogen on Small Grain
SP-1	Operational	Nutrient Management	*	Nutrient Management Plan
SP-2	Operational	Nutrient Management	*	Nutrient Management Plan
SP-3	Operational	Nutrient Management	*	Nutrient Management Plan
WL-3	Operational	Nutrient Management	*	Fescue Conversion /Wildlife Option
FR-1	Structural	Permanent Cover	46	Reforestation of Erodible Crop and Pastureland
SL-1	Structural	Permanent Cover	124	Permanent Vegetative Cover on Cropland
SL-11	Structural	Permanent Cover	11	Permanent Vegetative Cover on Critical Areas
SL-11B	Structural	Permanent Cover	*	Farm Road or Heavy traffic animal travel lane stabilization
WP-2A	Structural	Streambank Stabilization	*	Streambank Stabilization
WP-4	Structural	Waste Management	353	Animal Waste Control Facility
WP-4B	Structural	Waste Management	41	Loafing Lot Management System
WP-4C	Structural	Waste Management	86	Composting Facilities
WP-4E	Structural	Waste Management	*	Animal Waste Structure Pumping Equipment
WP-8	Structural	Waste Management	*	Relocation of CAFOs from Environmentally Sensitive Areas

Source: (Virginia Department of Conservation and Recreation, 2011). * Five or fewer adopting farms. Number withheld to protect confidentiality.

from the landowner for the contracted period of time for the implementation, usually 10 to 15 years, paying \$5 per acre per year of contracted period. This rate differs from the rate of CRFR-3, which is based upon 25% of cost of implementation and the extent of acreage benefiting from the BMP installation.

Cover crops were the most extensively adopted BMP in the entire watershed. The most widely adopted individual BMP was SL-8B, the small grain cover crop, which had 1,012 adoption events. The second most popular cover BMP was SL-8H, the harvestable cover crop, which had 308 adoption events. These two cover “harvestable” cover crops overshadow the third cover crop BMP WQ-4, the legume cover crop, which had a total of 57 adoption events in the watershed. It is assumed that one reason for the high levels of adoption of the harvestable cover crops could be due to the economic advantage from the harvested secondary crop.

The SL-6 BMP, grazing land protection, was the livestock exclusion BMP that was most extensively adopted in the Watershed, having 297 individual implementations. Grazing land protection involves stream exclusion fencing and installation of alternative watering systems and concrete feeding pads.

The SL-1 BMP, permanent vegetative cover of cropland, is the most highly adopted permanent cover BMPs in the Watershed, with 124 individual adoption events. This BMP basically converts an eroding crop field into pasture land or hay fields.

The second most extensively adopted BMP in the watershed was the WP-4 BMP, animal waste control facility, which had 353 individual adoption events in the Watershed. This BMP provides farmers with high concentrations of livestock a storage facility for animal wastes and controls the application of animal wastes back onto the land. This

BMP is unique because it provides funding for up to 75% of the total eligible costs of the installation and has an associated maximum tax credit of \$17,500. Tax credits are known to appeal to farmers, because ever-increasing property taxes on family farms are a major monetary burden for many farmers, especially those who have small operations and have inherited legacy farmland.

Every highly adopted BMP in the Watershed, except for CREP and WP-4 BMPs, are deemed “priority practices” by the Commonwealth of Virginia (Virginia Department of Conservation and Recreation, 2011). CREP BMPs have different funding allocations and are therefore not labeled priority practices. The WP-4 BMPs of waste management receive their own dedicated funding allocations because they are recognized by VACS as making significant reductions on non-point source pollution.

The map shown in Figure 8 displays the locations of individual BMP adoption events that took place in the Watershed from 1989 to 2008. The tributaries of the Watershed are also shown in this map, overlaying the points of BMP adoption events. A major clustering pattern is present in areas of the Watershed that directly drain into the confluence of the North River, Middle River, and South River into the mainstem of the South Fork Shenandoah River. This drainage area of clustered points comprises the study area of an in-depth analysis of BMP diffusion dynamics at play in the Watershed.

It is important to note that the individual points shown on the map do not represent unique adopters who implemented a BMP, but instead the points represent the locations where individual BMPs were implemented. Given the nature of the dataset, one farmer or farm has the possibility of having multiple points associated with them. It is possible that some of the points’ clustering behavior may be due to this phenomenon.

The possible hydrographic phenomenon and this caveat of repetitive clustering will both be explored further in Chapter 4.

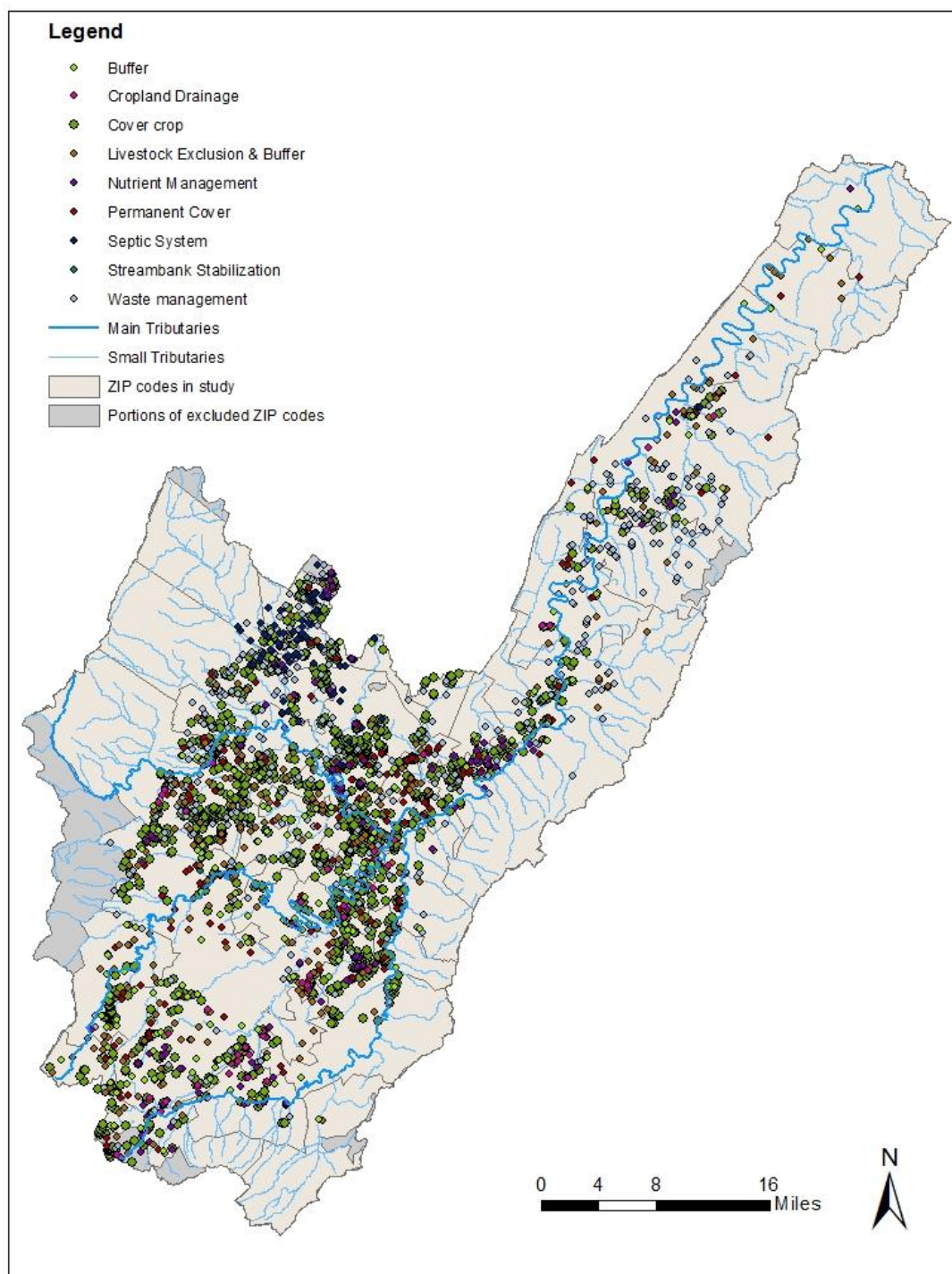


Figure 8. Map showing point data of BMP distribution within the watershed. Data source: VA DCR

3.3 BMPs IN THE STUDY AREA

The study area for this analysis comprises the three ZIP codes with the most BMP adoption activity (BMP “hot spots”) plus five other adjacent ZIP codes². The ZIP codes of with the highest levels of adoption events were: Weyers Cave, Mount Solon, Mount Crawford, and Port Republic. The additional ZIP codes included in the study area are: Grottoes, Fort Defiance, Mount Sidney, and Bridgewater, see figure 9. Note that a few of these ZIP codes do not have high densities of BMP activity; Bridgewater, Mount Sidney, and Fort defiance have less than 12 BMPs per ten farms. These farms were included in this analysis to ensure an unfragmented view of this hotspot analysis zone. Including these ZIP codes allows for the inclusion of diffusion corridors. These low density ZIP codes must be included in this analysis because to exclude them would also exclude important BMP implementation events that may have influenced the adoption of BMP's in adjacent high density ZIP codes.

It is important to note that ZIP code boundaries were used in this analysis because they were the smallest level of spatial aggregation for which the US Census of Agriculture had data. The boundaries of the ZIP codes are spatially arbitrary as they do not provide any physical barrier for BMP implementation; however the ZIP code polygons are useful because they allow for analysis of BMP adoption events based upon statistical agricultural information about the farming areas.

² Due to the investigative aim of this thesis, including the entire watershed is considered outside the scope of these analyses. See Chapter 1, p. 3, for additional background information about the rational for choosing this subset of ZIP codes.

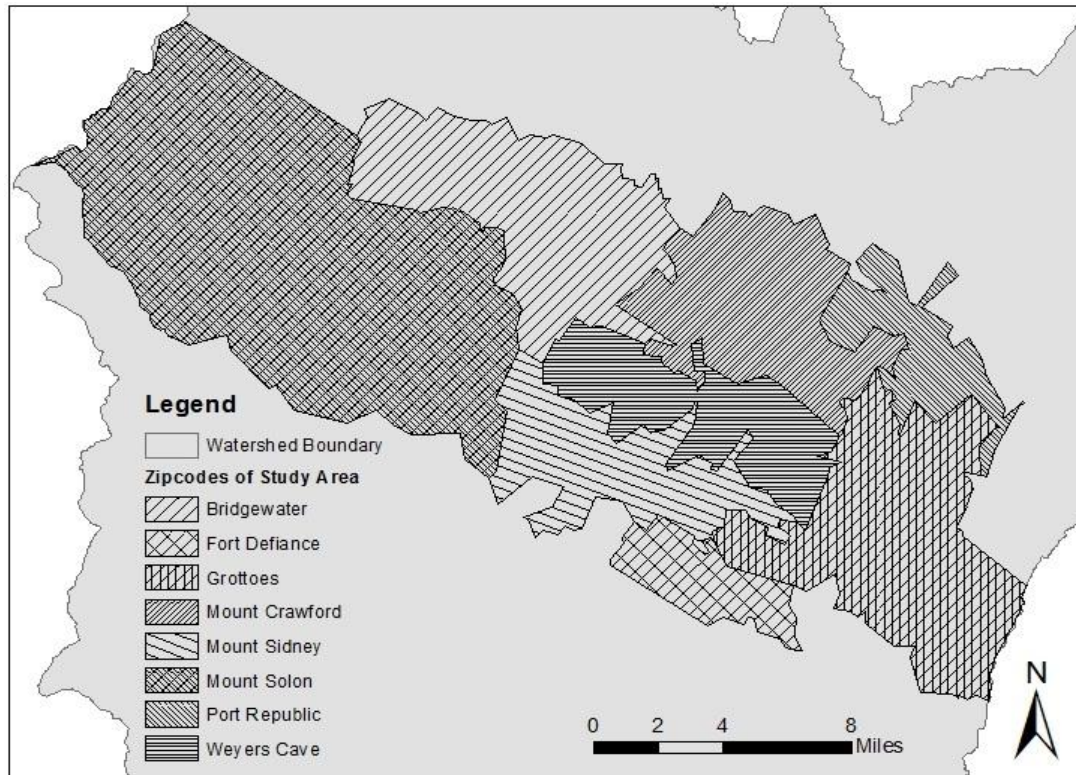


Figure 9. Map Showing the ZIP codes comprising the study area. Data source: VA DCR and ESRI.

The Rapid Watershed Assessment conducted by Mizel, Papadakis, Degner, Shepard, & Havinga (2008) categorized the individually implemented BMPs into nine categories:

1. Riparian vegetative buffer
2. Annual cover crop
3. Cropland drainage installation
4. Livestock exclusion from streams
5. Nutrient management
6. Permanent vegetative cover
7. Septic system installation
8. Stream bank stabilization
9. Waste management

Two of the BMP categories presented in the RWA, septic system and stream bank stabilization, were excluded from the analysis in this dissertation. The BMP category of stream bank stabilization was excluded because the implementations of this BMP

occurred outside of the study area for this analysis. The BMP category of septic system installation was excluded from the study because these occurred mostly within the city of Harrisonburg and because septic system BMPs are not part of the VACS program as agricultural BMPs. Therefore only the remaining seven BMP categories were included in the study. The palette of different BMPs implemented within the study area is not as diverse as that of the entire Watershed (Table 2).

Table 2. Description of the BMPs in the study area and their frequencies.

VACS Code	Structural or Operational	BMP Type	Quantity	Description of BMP
CP-21	Structural	Buffer	*	CREP Filter Strip (Rental only)
CP-22	Structural	Buffer	22	CREP Riparian Forest Buffer (Rental only)
CP-22B	Structural	Buffer	*	CREP Riparian Forest Buffer (Rental only)
CRFR-3	Structural	Buffer	22	CREP Riparian Forest Buffer
FR-3	Structural	Buffer	*	Woodland Buffer Filter Area
WQ-1	Structural	Buffer	*	Grass Filter Strips
SL-8B	Operational	Cover Crop	497	Small Grain Cover Crop for Nutrient Management
SL-8H	Operational	Cover Crop	136	Harvestable Cover Crop
WQ-4	Operational	Cover Crop	46	Legume Cover Crop
SL-3	Operational	Cropland Drainage	8	Stripcropping Systems
WP-3	Structural	Cropland Drainage	7	Sod Waterway
SL-6	Structural	Livestock Exclusion	95	Grazing Land Protection
SL-6B	Structural	Livestock Exclusion	*	Alternative Water System
WP-2	Structural	Livestock Exclusion	19	Stream Protection
NM-1	Operational	Nutrient Management	7	3 Year Contract for Nutrient Management Plan
NM-3	Operational	Nutrient Management	16	Sidedress Application of Nitrogen on Corn
NM-4	Operational	Nutrient Management	*	Late Winter Split App. of Nitrogen on Small Grain
FR-1	Structural	Permanent Cover	18	Reforestation of Erodible Crop and Pastureland
SL-1	Structural	Permanent Cover	50	Permanent Vegetative Cover on Cropland
SL-11	Structural	Permanent Cover	*	Permanent Vegetative Cover on Critical Areas
SL-11B	Structural	Permanent Cover	*	Farm Road or heavy traffic animal travel lane stabilization
WP-4	Structural	Waste Management	114	Animal Waste Control Facility
WP-4B	Structural	Waste Management	20	Loafing Lot Management System
WP-4C	Structural	Waste Management	24	Composting Facilities

Source: (Virginia Department of Conservation and Recreation, 2008) (Virginia Department of Conservation and Recreation, 2011). * Five or fewer adopting farms. Number withheld to protect confidentiality.

A total of 1,117 BMP adoption events occurred within the eight ZIP codes of the study area from 1989 to 2008, which totals 40.5% of all BMP adoption events in the Watershed occurring in the subset study area. The study area is comprised of 25% of the total farms within the Watershed. Table 3 provides a brief comparison of the different BMP types in the Watershed and in the subset study area. As seen in table 3, the prevalence of the Watershed's most highly adopted BMPs remains consistent within in the subset study area as well.

The study area comprises 49% of all cover crop BMPs implemented in the watershed. Meaning that out of all 33 ZIP codes of the Watershed, nearly half of the total cover crop adoption activity is present within these eight ZIP codes alone. The other BMP types that revealed very high percentages of adoption activities within the study area were permanent cover, livestock exclusion, and waste management.

Table 3. Quantities of adoption events of different BMP categories in the study area and the watershed.

BMP Type	Study Area Quantity	Watershed Quantity	% total BMPs
Buffer	51	186	27%
Cover Crop	679	1377	49%
Cropland Drainage	15	50	30%
Livestock Exclusion	118	351	34%
Nutrient Management	24	126	19%
Permanent Cover	72	182	40%
Waste Management	158	482	33%
Total	1,117	2,754	40.5%

Source: (Virginia Department of Conservation and Recreation, 2008)

These data appear to show a bias towards those BMPs deemed by DCR as “priority practices; possibly due to the heavy promotion of these BMPs by SWCDs and NRCS conservationists. However, the properties of these intensively adopted BMPs

could be determining their rates of adoption. The levels of a BMPs relative advantage, compatibility, observability, trialability, complexity, expense, and even the length of time required to commit are all properties and characteristics of these individual BMPs that determine their adoptability. The properties which have a positive correlation with increased adoption are: relative advantage, compatibility, observability, and trialability, see Table 4. As the degree to which these properties increase so also does the BMP's adoptability. Inversely, the three remaining properties, complexity, expense, and years of commitment, all correlate negatively with adoptability.

Under these notions, it makes sense that cover crop BMPs, which have the highest rates of adoption in the study area, also have very high levels of positively correlating properties and very low levels of negatively correlating properties. Consistent with these suppositions, nutrient management and buffer BMPs, which have very low levels of positively correlating properties and high levels of negatively correlating properties, have low rates of adoption in the study area. Given these correlations between a BMPs properties and its adoption rate, it is important to consider the characteristics of BMPs as a driving force behind their clustering behavior in the subset study area and in the Watershed.

Table 4. Chart showing the different intensities of properties for different BMP types.

BMP Type	Relative Advantage	Compatibility	Observability	Trialability	Complexity	Expense	Operational or Structural*	Commitment (years)
Buffer	-	--	+	--	+	+	S	5 to 15
Cover Crop	++	++	++	++	-	-	O	1
Cropland Drainage	+	-	-	+	+	+	O & S	5 to 10
Livestock Exclusion	-	--	++	--	+	++	S	5 to 10
Nutrient Management	--	--	--	+	++	-	O	1 to 3
Permanent Cover	-	-	++	-	-	+	S	5 to 10
Waste Management	+	-	+	--	++	++	S	10

Symbols: --, very low; -, low; +, high; ++, very high. * O= Operational Source, S= Structural. Source: (Virginia Department of Conservation and Recreation, 2011)

As previously discussed (Chapter 1, p. 9 and Chapter 2, p. 19), the success of a BMP's adoption in the watershed may be partially determined by whether the BMP's characteristics, this also includes whether it is structural or operational in nature. Structural BMPs such as animal waste control facilities and livestock exclusion fencing require a significant capital investment as well as a great deal of technical and coordination assistance. Operational BMPs such as cover crops and nutrient management are less resource intensive and present less of a financial and technical barrier to farmers than structural BMPs. The large adoption rate of cover crop BMPs, an operational BMP, is consistent with the supposition that BMPs with an operational nature have a higher degree of adoptability than those BMPs with a structural nature.

3.4 FARMER RECEPTIONS TO BMP CONSERVATION PROGRAMS

Rogers (1983) states that diffusion of an innovation requires time, an innovation to adopt, communication channels to educate and inform about the innovation, and the interactions of a social system. Thus far in the discussion about BMP adoption diffusion in the Watershed and the subset study area, the properties of the innovation and communication channels have been discussed in depth, while the properties of the social system are left to be addressed. This section aims to provide a glimpse into the social system of the Watershed's community of farmers and also describe the various obstacles and resistances present within this social system with regards to VACS BMP promotion and implementation.

When studying the diffusion of an innovation throughout a specific community, it is essential to fully consider the social dynamics and characteristics of the community of potential adopters. As discussed in Chapter 2, there are three major social factors at play in innovation adoption diffusion; socio-cultural, socio-economic, and political-institutional (Morrill, Gaile, & Thrall, 1988). In the case of farmer adoption of VACS BMPs, these three social dimensions noticeably impact farmer adoption decisions. Papadakis (2008) conducted extensive content analysis of documents summarizing local stakeholder feedback on BMPs at a number of community meetings and workshops held in the Watershed. Stakeholder's opinions (including farmers) about BMP programs and conservation issues were analyzed for common themes, problems, attitudes, and concerns that might affect adoption of BMPs by the agricultural community. Emerging from this content analysis are farmers' observations and perceptions about VACS and BMP promotion in the watershed, which can be grouped into three important considerations:

1. Socio-cultural and socio-economic differences between farmers and conservation agents and technicians.
2. Economic and technical restraints of BMPs
3. Farmers' perceptions and level of trust in government programs.

SWCD field agents are often socio-economically and socio-culturally heterophilous to the majority of the farmers in the community and have issues with establishing trust with farmers. Field agents and technicians have more formal education and higher income than the farmers in the community. SWCD field agents may be perceived as too “liberal” or are labeled environmentalists (Papadakis, 2008). Technicians from DCR, SWCDs, EPA and NRCS are often considered to be “outsiders” who do not appreciate or understand farmers. These agents often speak too technically and neglect to consider the benefits and disadvantages of BMPs for farmers. Farmers value peer testimony and are more receptive to a BMP when they have seen it implemented on a working farm.

The economic and technical restraints that revolve around BMPs involve the costs and complexity of the BMP installation as well as the perceived “red tape” and bureaucracy of VACS. Many structural BMPs, even after government assistance, require a significant capital investment that many farmers are unable to afford. In other cases, in order to receive funds for a BMP, one must adhere strictly to the guidelines set out in the contract. One such instance of this inflexibility is the width requirement on buffer construction, the buffers area is required to be 35 feet from either side of the river. For farmers with smaller sized farms, this width requirement is not possible for them to adhere to as it takes too much of their land out of production. Farmers argue that many cost share BMPs are too exclusive and are unfairly focused on larger farms. The

bureaucracy of the system with all of the requirements farmers and their farm operations have to meet to qualify for VACS BMPs are extremely frustrating to the farming community. Farmers of the support groups argue that there would be more participation in VACS BMPs if more farmers were involved in the BMP writing process and if VACS had less broad bureaucracy and more coordination focused on local issues and concerns.

In many cases, farmers have had negative experiences with cost-share BMP implementation or know someone who has had a negative experience with the DCR, NRCS, or local SWCD. There are major issues with the older generation of farmers not trusting the government. The majority of problems that farmers seem to have with DCR, local SWCD, and NRCS stem from lack of funding and staff. There are also issues with coordination of activities between the various agencies and inconsistencies in the messages they relate to farmers. This inconsistency and lack of locally focused programming aid to farmers' negative perception of government programs such as VACS. Another major deterrent of participation is the uncertainty of funds from year to year. The funding for these various programs is often volatile and can change drastically each year, see Figure 7.

One repeating comment of farmers in the stakeholder analysis about BMPs was that they prefer a short contract period and limited governmental interference only for technical assistance. The widespread adoption of cover crops in the watershed is therefore consistent with the farmers' preference for BMPs with short contract periods.

3.5 SUMMARY AND IMPLICATIONS

In summary, the Commonwealth of Virginia's promotion of BMP implementation is basically exclusively comprised of VACS, administered by the DCR, NRCS and local SWCDs. Funding for VACS comes from Water Quality Improvement Fund (WQIF) state resources and several federal grants. Annual funding for cost-share BMPs is volatile and has shown a pattern of changing drastically from year to year. In regards to funding, 80% of funding for VACS is dedicated to the implementation of those BMPs deemed "priority practices" in the DCR's manual for VACS. Local SWCDs are urged by the DCR to actively promote "priority practices" in their districts.

Since 1989 there have been a total of 2,754 individual BMP adoptions in the South Fork Shenandoah River Watershed, with 1,117 of these events occurring in a study area in the Watershed that shows a "hotspot" of BMP adoption activity. These findings were originally displayed and discussed in the Rapid Watershed Assessment of the Watershed (Mizel, Papadakis, Degner, Shepard, & Havinga, 2008). This chapter of this thesis attempts to address the BMP adoption activity of ZIP codes comprising this "hotspot" study area in order to identify any prominent mechanism for this clustering. Given this goal, the BMP adoption activity, social system and geography of the study area was examined to tease out any properties of individual BMPs, of the social system, or of the change agency that could be responsible for this clustering of adoption activity in this study area.

Everett Rogers (1983) established that innovations have properties that determine their adoptability; relative advantage, compatibility, trialability, observability, and complexity. In this analysis, the different BMPs were placed into nine different categories

and their adoptability was analyzed based upon their unique levels of the aforementioned properties as well as their expense and required years of commitment, see Table 4. 0

It was discovered that based on these unique levels of properties, some BMPs have higher levels of adoptability than others. The only BMP with a distinctly high level of adoptability was the cover crop BMP, which is also the most widely and actively adopted BMP in the Watershed. The BMPs with the lowest levels of adoptability were nutrient management and buffer BMPs, which were also the least adopted BMPs in the Watershed.

The observations and opinions of farmers about VACS and government agencies are very important to consider when studying the spread of BMP adoption throughout the watershed. A brief discussion of their farmers' perceptions was included in this analysis. It was discovered that farmers battle many economic and technical restraints VACS. Also discovered was that the possible disjointed communication structure about VACS due to possible social differences between farmers and change agents and farmers' possible distrust of government programs.

From this analysis of BMP activity and properties of the individual BMPs, and a closer examination of the social perceptions of the community it was discovered that there may be three possible forces at play that may have influenced clustering of BMP adoption in the subset study area.

The geographic location of the study area. The hotspot study area is in close proximity of the confluence of the North River, Middle River and South River into the mainstem of South Fork Shenandoah River.

The promotion of priority practices. The majority of BMPs that were most actively adopted were deemed “priority practices”. It is noteworthy, that 78% of the BMP adoption events that occurred in this study area were of BMPs that are designated by Virginia DCR in the 2011 VACS manual as “Priority Practices”. (Virginia Department of Conservation and Recreation, 2011). Presumably the promotion of “priority practices” took place throughout the Watershed and this bias for priority practice BMPs would also be evident in BMP adoption events of the entire Watershed.

The properties of the BMPs that define their adoptability. There is a seemingly strong consistency between a particular BMP’s adoptability and its intensity of adoption in the watershed. The BMP with the highest degree of adoptability, the cover crop BMP, was also the most widely and actively adopted BMP in the watershed. In addition, the two BMPs with the lowest degree of adoptability, nutrient management and buffer BMPs, were also the least adopted BMPs in the Watershed. Presumably the adoptability of the different BMPs based upon their unique properties is not exclusive to the study area and has the same degree of influence over the BMP adoption activity in the entire Watershed. However there is possibly some underlying factor at play that has made BMPs inherently more adoptable in the ZIP codes of the subset study area. This inquiry will require a thorough comparison of the physical and social characteristics of the ZIP codes in the subset study area and the remainder of the ZIP codes in the Watershed

The findings from the analysis presented in this chapter help to identify motivations and influential forces that are inherent in the innovation, the social system,

and in the geographic location. However, there is also the possibility that spatial diffusion dynamics are also a driving force behind this clustering of adoption activity in the Watershed. The following chapter will address the possibility of BMP adoption diffusion throughout the Watershed being driven by contagion or even hierarchical contagion effects.

4. FINDINGS & DISCUSSION

The previous chapters presented essential information about innovation diffusion and the necessity of understanding the complex dynamics of social systems, communication channels, and properties of innovations for the successful diffusion of an innovation. The theory of innovation diffusion was brought into the perspective of the Watershed with an in-depth description and discussion of the social characteristics of the Watershed community and the unique properties of the BMPs that determine their adoptability. Chapter 3 concluded with a summary of three possible drivers of BMP adoption intensity in the study area. Temporal and spatial diffusion dynamics of the Watershed were briefly touched upon and the elements of spatial diffusion were discussed in depth.

This chapter aims to bind all of these discussions and analyses together to summarize the findings of the work of this thesis and provide temporal analyses to support postulations presented in early chapters. The first section of this chapter will give an overview of temporal diffusion and its importance for understanding trends and detecting where in the diffusion of innovation process a particular innovation is at a given time. Then a brief temporal analysis will be presented on the BMP adoption data for the study area.

The second section of this chapter will provide a brief spatial analysis of the BMP adoption diffusion across the study area. This section will discuss the temporal and spatial diffusion of BMP adoptions within the specified study area in the watershed. A map sequence will be displayed and discussed that shows the adoption diffusion of all

cumulative BMP adoption events throughout the subset study area from 1989 to 2008. A statistical test will determine the presence of clustering adoption events in the study area. An analysis will be conducted that determines whether the diffusion of farms can be attributed to more than just a handful of actively adopting farms. Inspection of maps will try to establish supporting evidence for any kind of contagion effect on the innovation's diffusion.

The chapter will conclude with a summary of the key findings of the analyses, research, and literature review pertaining to the intensity of BMP adoption activity in the study area.

4.1 TEMPORAL DIFFUSION OF BMP ADOPTION IN THE STUDY AREA

This section seeks to examine the temporal trends and patterns of BMP adoption diffusion in the study area. It is useful to study the frequency of adoption of an innovation over time, as it can help to identify the extent to which an innovation has diffused through a social system. Rogers (1983) defines the differing adopter types by the times in which certain percentages of adopters have adopted an innovation. This method can be used to determine which category of adopters is currently adopting the innovation and can help with innovation promotion by give clues on some possible characteristics and motivations of those adopters. Rogers' (1983) graph, shown in figure 10, identifies the time period comprised of adoptions by the last of the Early Adopters up to the middle of the Early Majority.

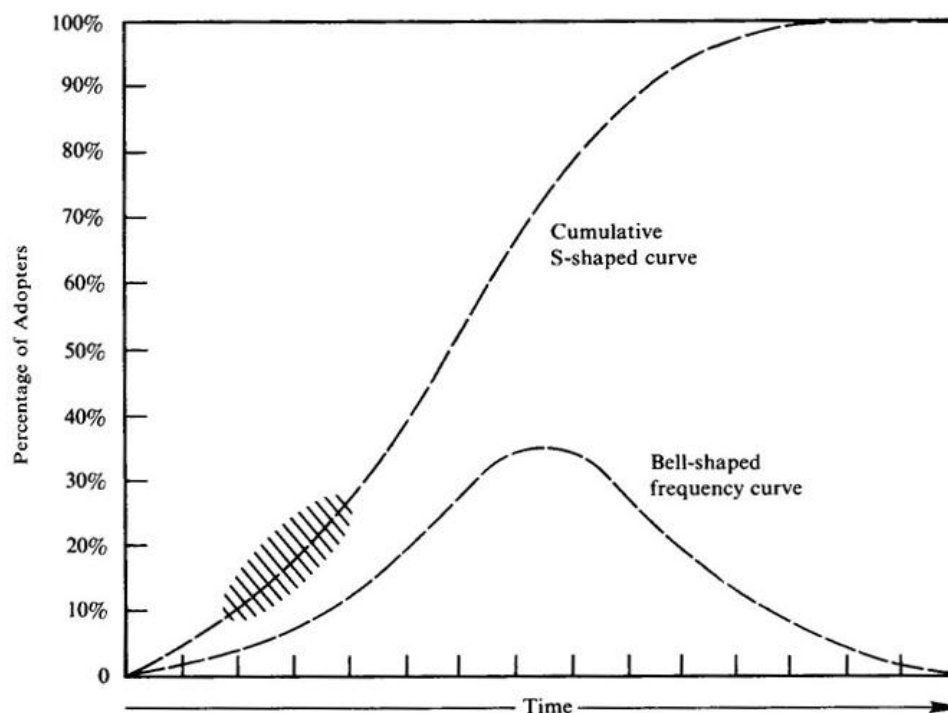


Figure 10. Graph of bell-shaped and S- shaped curves depicting diffusion of adoption of an innovation over time. The cross-hatched area on the graph represents the time period when innovation adoption begins to take hold in the society. Source: (Rogers, 1983).

The BMPs studied in this dataset are either structural or operational in nature, meaning that some BMPs are one time implementations, such as installation of livestock exclusion fencing or construction of animal waste control facilities, while others have a repetitive nature and can be readopted, such as planting annual cover crops or abiding by a nutrient management plan. The repetitive nature and the ability for the adopter to sporadically reject or readopt, make it very difficult to quantify the percentage of total potential adopters who are adopting an operational BMPs at any given. Operational BMPs are therefore not well represented by the S-shaped logistics curve or bell-shaped curve showing normality. The structural BMPs, having less flexibility and more definable adopter percentages than operational BMPs, generally fit these traditional models of diffusion quite well.

Studying adoption frequency can also help identify possible correlations between adoption activity and external pressures or incentives that could possibly be influencing adoption. In the case of VACS BMP adoption, the participation in BMPs is determined by the amount of funding allotted to VACS each year. As was discussed previously in Chapter 3 (p. 36), funding for VACS has proved to fluctuate greatly from year to year. The adoption frequency of VACS BMPs per year was plotted against the amount of funding per year from 1989 to 2008 for the entire watershed. The result shows a pronounced correlation between funding and participation. Another graph was produced, this time comparing the adoption frequency of VACS BMPs per year in the study area and the amount of funding for VACS per year from 1989 to 2008, see figure 11. Again this suggests a clear correlation between funding and participation.

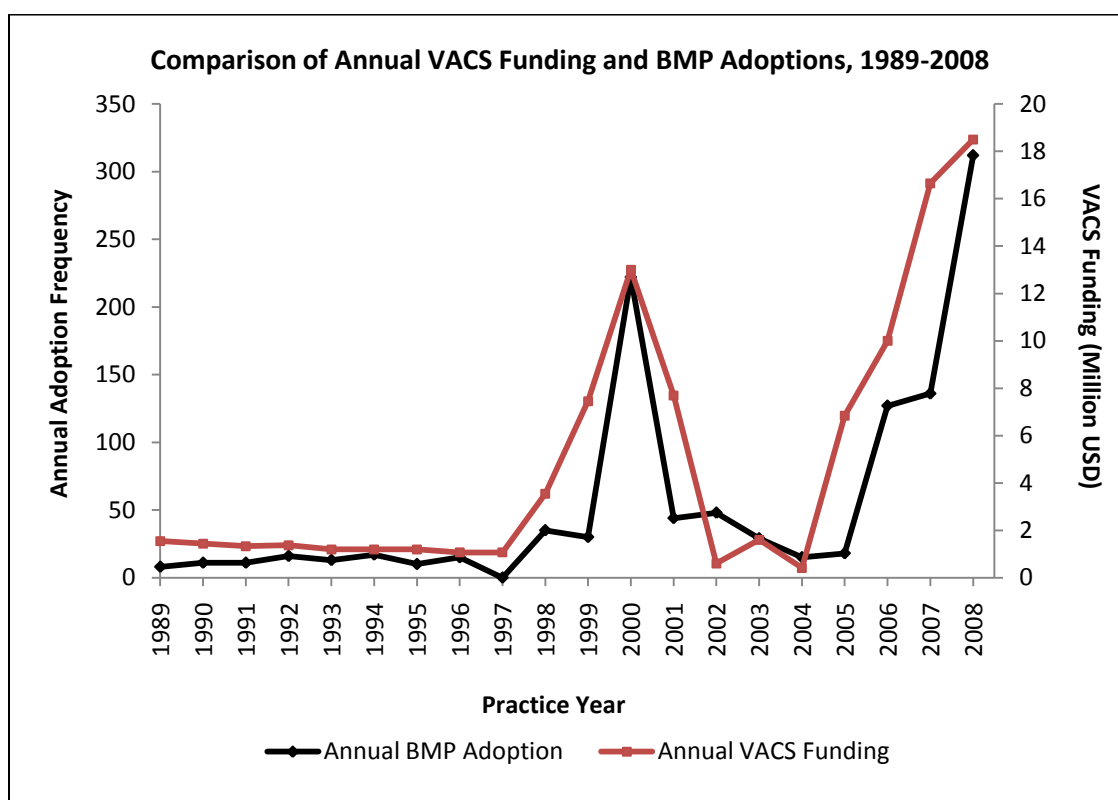


Figure 11. Total BMP participation including all BMPs in the study area from 1989-2008. Source: VA DCR

By graphing out the adoption frequencies of each of the seven BMP types, more detailed information about which of the BMPs' rates of adoption responded most obviously to the fluctuations in funding may be seen (figure 12). There is a seemingly positive correlation between increase in funding and increase in adoption rate of cover crop BMPs. The year 2000 saw a spike in cover crop participation of up to 170 participants in the study area, while in that same year VACS funding increased from about 7.5 million USD to over 13 million USD. In 2001, there was a drop of both funding and participation in BMPs to nearly the same amounts of 1999. This sudden increase and resultant drop in cover crop BMP adoption activity could likely have been due to increase in the dedicated allotment of financial assistance from the VACS program for annual cover crop plantings for the 2000 practice year. This hypothesis is further supported by the strong correlation present between the increases in funding from 2005 to 2008 and the increase in adoption frequency from 2006 to 2008. The magnitude of cover crop BMP adoptions in the study area is far greater than that of any other BMP type included in this study area.

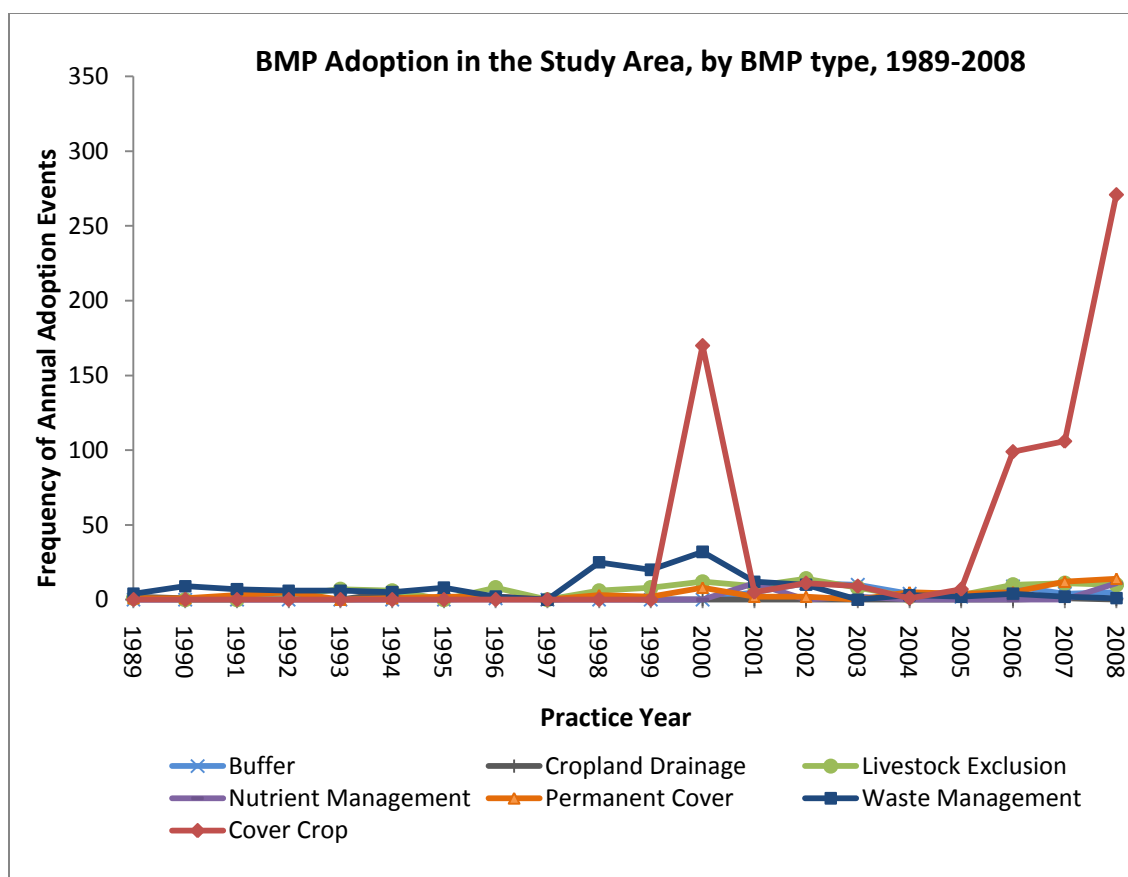


Figure 12. BMP Adoption in the Study Area, by BMP type, 1989-2008

A possible correlation between waste management BMPs and the amount of VACS funding was also determined after comparing the adoption frequencies of individual BMP types to amounts of VACS funding per year. The 1998 practice year saw an increase in funding from approximately 1 million USD, the average amount of annual funding for the program since 1989, to over 3.5 million USD. Also seen in 1998 was sudden spike in waste management BMPs from zero adoptions in 1997 to 25 adoptions in the 1998 practice year. Waste management BMP adoption remained near 30 participants each year until 2001 when VACS funding plummeted to only 60,000 USD. Further research found that extensive promotion and funding was given to VACS BMP WP-4, construction of animal waste control facilities, and resultantly the numbers of this

particular BMP spiked (Virginia Department of Conservation and Recreation, 2011). The construction of an animal waste control facility is very expensive and most farmers require financial assistance from government funds in order to implement this BMP.

As discussed previously in this chapter (p. 58), the temporal analysis of data can reveal trends and patterns that may be linked to external pressures and influences. Such was the case with the temporal analysis of these BMP adoption data. The analysis of the adoption frequencies of the seven different BMP types occurring in the study area revealed positive correlations between funding for VACS and BMP adoptions rates. Waste management practices were greatly increased due to dedicated funding for the BMP WP-4, animal waste control facility, a BMP that is well known to be very costly to implement. Another correlation that was found, seemingly the stronger of the two correlations was that of cover crops and its positive correlation to VACS funding. The instances of cover crop BMP adoption appears to be tightly linked with availability of funds. Also of note, was the cover crop BMP's enormity of adoption events compared to the number of adoption events from other BMP types. One overarching observations about the BMP adoption events of the different BMP types data that came from this temporal analysis was: all BMP types had consistently low adoption frequencies, usually ranging from one to seven adoption events per BMP type per year in the study area, and interrupted by spikes of activity from cover crop and waste management BMPs.

4.2 SPATIAL DIFFUSION OF BMP ADOPTION IN THE STUDY AREA

The previous section highlighted key temporal trends present in the dataset of BMP adoption frequency in the study area. As was discussed in Chapter 3 (p.29), the characteristics of the community of adopters, the many unique properties of BMPs, and the status of communication channels all work to determine the successful diffusion of BMP adoption. This section expands on the temporal trends revealed in the previous section and the social dynamics, by additionally examining the spatial attributes of the diffusion of BMP adoption across the region, their spatial diffusion. As was previously discussed in Chapter 2 (p.25), spatial diffusion is the spread of a phenomenon over geographic space (Morrill, Gaile, & Thrall, 1988). A phenomenon is born and moves from its place of origin to other locations. There are three main types of spatial diffusion that are considered when studying spreading phenomenon. These three types are contagious expansion, hierarchical expansion, and relocation diffusion.

A sequence of maps was compiled in order to visualize both the spatial and temporal elements of BMP adoption spread across the subset study area. For a given year the points presented in the map include all individuals who adopted BMP in that year or in previous years. All BMP adoption events of the entire twenty year dataset are accounted for in this analysis, with each individual point shown in the maps representing a single BMP implementation at a specific geographic location. The maps are cumulative, in that the map for a given year shows all BMP adoptions prior to and including that year. In this way, we can see the temporal diffusion of the BMP events. The maps sequencing the accumulative BMP adoption diffusion from 1989 to 2008 are depicted in figures 13-16.

Cumulative Adoption of All BMP Types Combined, 1989-1994

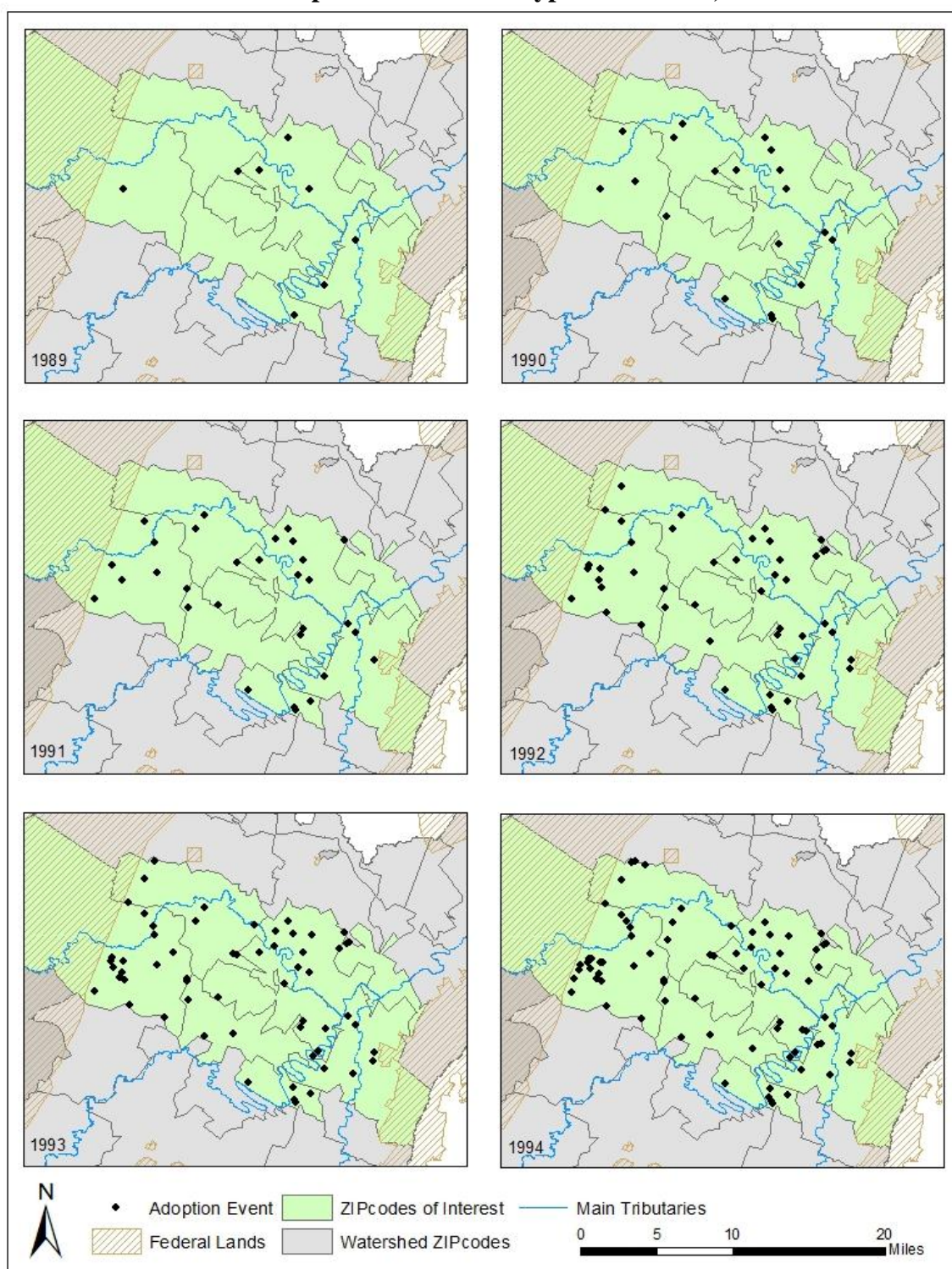


Figure 13. Map sequence showing the diffusion of all BMPs cumulatively in the study area, 1989-1994.

Cumulative Adoption of All BMP Types Combined, 1995-2000

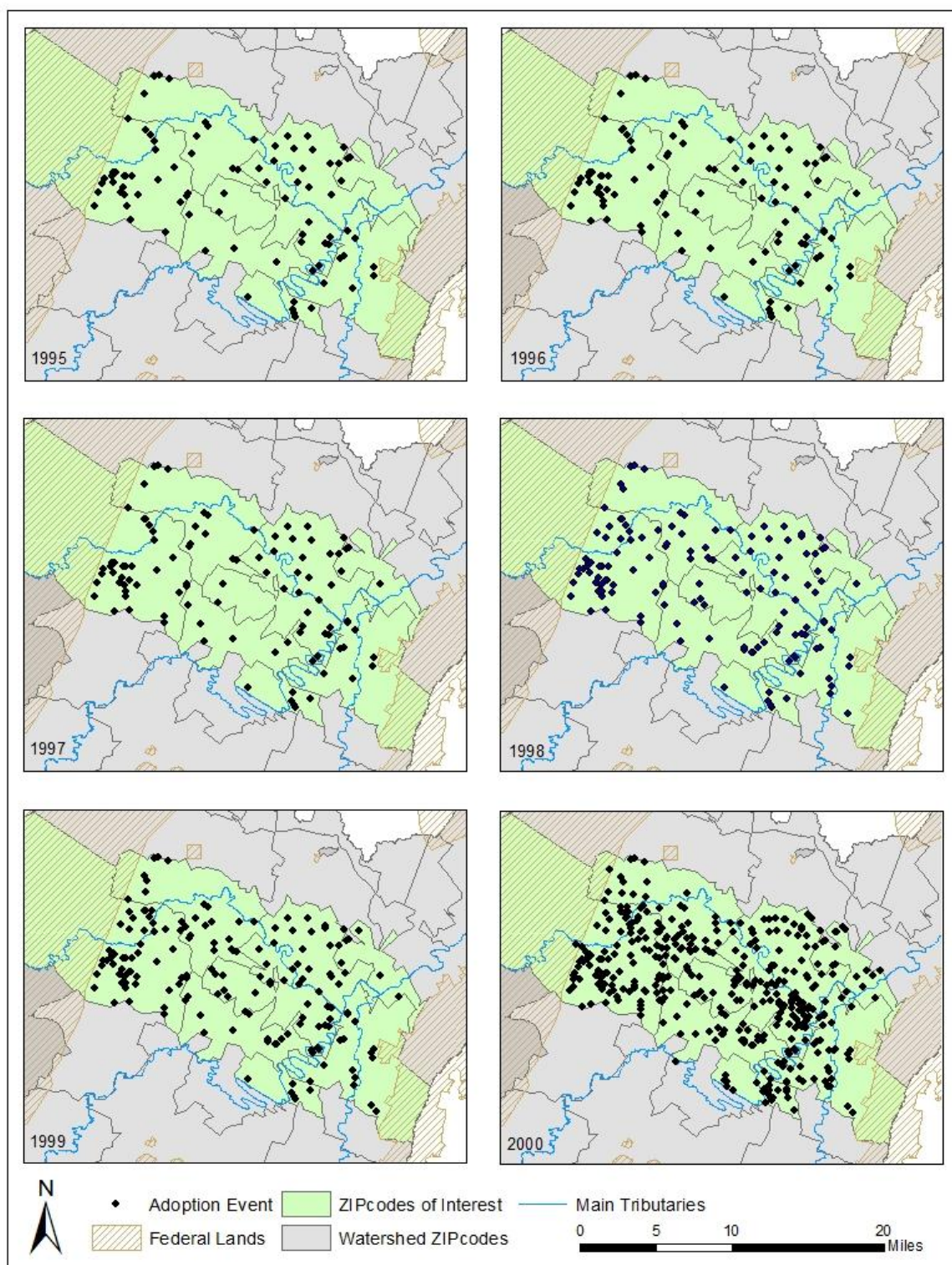


Figure 14. Map sequence showing the diffusion of all BMPs cumulatively in the study area, 1995-2000.

Cumulative Adoption of All BMP Types Combined, 2001-2006

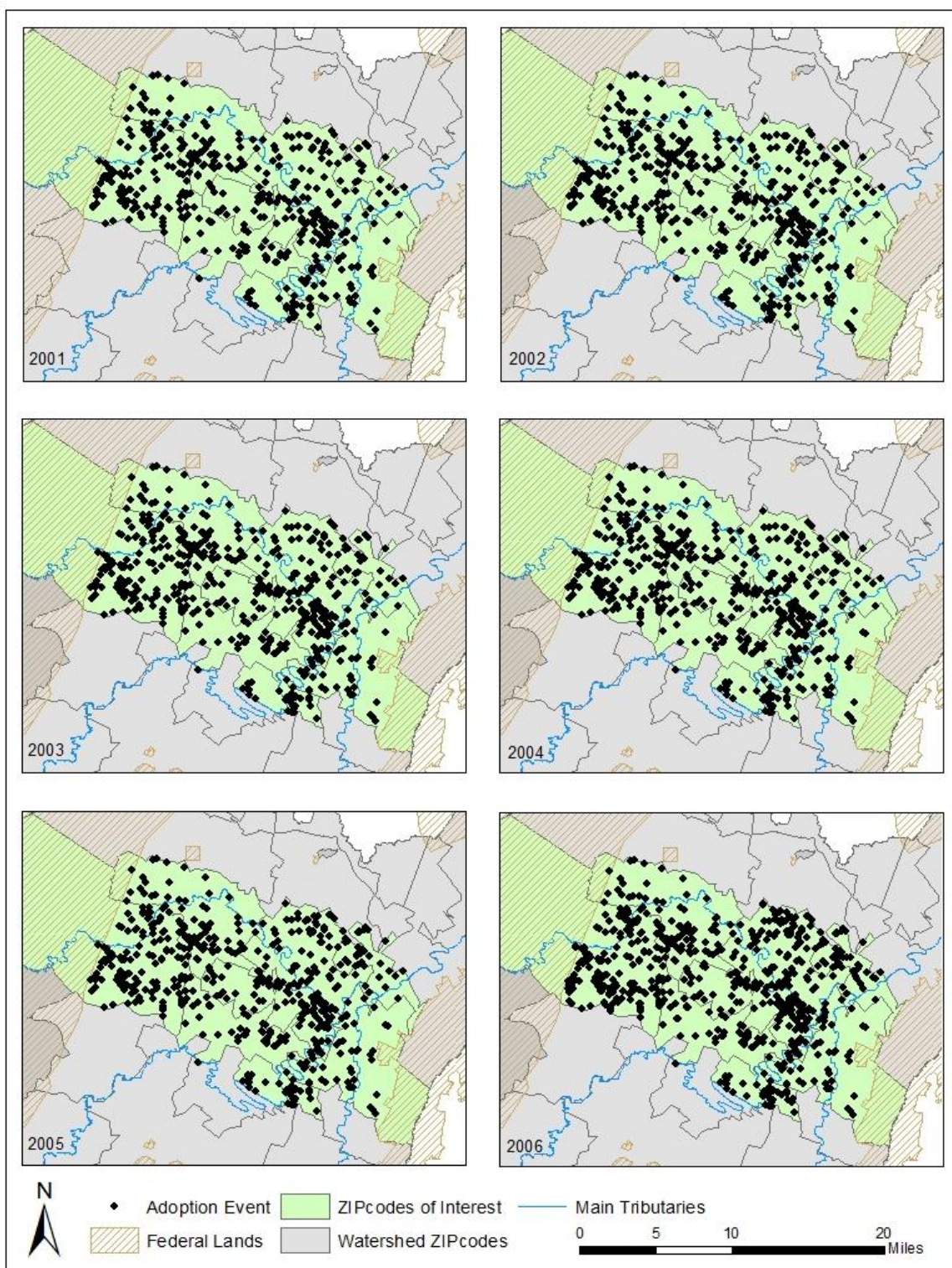


Figure 15. Map sequence showing the diffusion of all BMPs cumulatively in the study area, 2001-2006.

Cumulative Adoption of All BMP Types Combined, 2007-2008

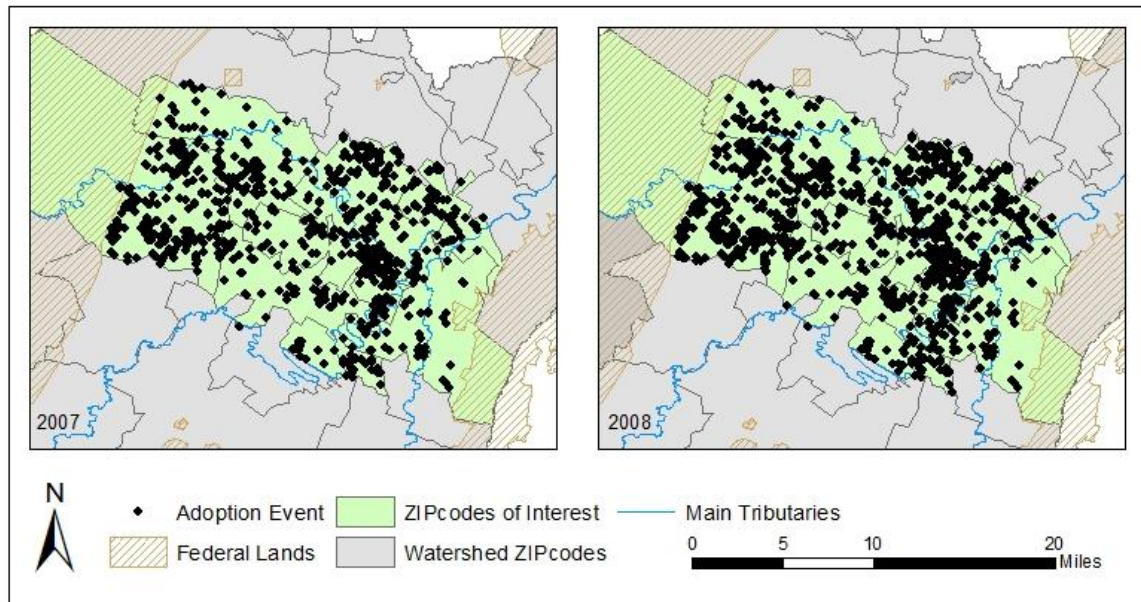


Figure 16. Map sequence showing the diffusion of all BMPs cumulatively in the study area, 2007-2008.

This sequence of maps showing cumulative BMP adoption diffusion throughout the study area seems to demonstrate clustering patterns. This clustering is clearly evident by the year 2000 and is increasingly visible after the inclusion of adoption activities from 2006 practice year, 2006 map inset of figure 15. The clustering pattern intensifies and is further defined after the inclusion of adoption activities from 2008 practice year, 2008 map inset of figure 16. Even as bold and seemingly apparent as this clustering pattern appears to be, it is important to establish statistical support for this possible clustering behavior of the point data.

4.2.1. AVERAGE NEAREST NEIGHBOR ANALYSIS

Average Nearest Neighbor Analysis is a spatial statistical test that is used to analyze point data to determine likelihood that the points are in a specific location due purely to random dispersion. This spatial statistic does not evaluate, as the name seems to imply, the proximity of one farmer “neighbor” to another. Instead, what it does do is use the point data of BMP adoption events to calculate the likelihood that the points are the result of purely random dispersion within a certain extent of area. The geographic extent of the study area is determined by the statistical test to be a rectangle of best fit around the data points, the rectangle size can be designated manually to give a more accurate measurement of the parameter of the area. The test calculates the distances between all of the points in the BMP data within the extent and comes up with an average distance and compares that distances to the theoretical distance it calculates for that same area if all points were randomly distributed across geographic space.

An average nearest neighbor spatial statistical test was performed on the cumulative BMP adoption data points as of 2008 practice year for each of the different BMP types as well as for all of the BMP types combined. This test was conducted to support the observation that the BMP’s seemingly clustering behavior is not merely visual apparition. The results of this test can be found in Table 5 below. As stated in the table description, a critical value (z-score) of less than -2.58 corresponds with less than 1% likelihood that this clustered pattern could be the result of random chance. All of the BMP types, except waste management BMPs, tested positive for clustering.

Table 5. Results on Average Nearest Neighbor Statistical Test on the cumulative totals as of practice year 2008 for the different BMP types as well as for the cumulative total of all BMP types combined.

BMP type	p-value	z-score	Nearest neighbor ratio
All BMPs	0.000000	-15.591889	0.756140
Buffer	0.000001	-4.929887	0.639155
Cover Crop	0.000000	-16.630029	0.666399
Cropland Drainage	0.008987	-2.612556	0.647395
Livestock Exclusion	0.000000	-7.073023	0.659644
Nutrient Management	0.005024	-2.805473	0.700657
Permanent Cover	0.000000	-6.907568	0.598808
Waste Management	0.650105	-0.453616	0.981136

A critical value (z-score) of less than -2.58 corresponds with less than 1% likelihood that this clustered pattern could be the result of random chance. A z-score between -1.96 and -2.58 corresponds with less than 5% likelihood that this clustered pattern could be the result of random chance. A z-score between -1.65 and 1.65 indicates that the pattern is not significantly different than random. The area value used in the nearest neighbor analysis was 581,168,598.60 square meters. The Euclidean distance method was used in this analysis.

There are a few limitations to this statistical test that should be explained and accounted for. One such limitation with this statistical test is that it will not adequately discern clustering behavior of points when it is in its early stages. Another possible limitation to this test is in how it determines the extent of the study area. The study area in this case is not a perfect rectangle. The further the study area's shape is away from a rectangle, the less precise the p-values of the z-scores. In this current case, this will tend to overstate the statistical significance slightly. However, because the study area is closely approximated by a rectangle, and because the statistical significance of all but one of the BMP's (Waste Management) is well below 0.01, it is reasonable to conclude that, as of 2008, clustering is present with all of the BMP's except Waste Management.

4.2.2 PARCELS' BMP ADOPTION DENSITIES

The statistical support for clustering of adoption events from the Average Nearest Neighbor Analysis does not differential between individual adopters, only individual adoption events. One of the questions that this thesis attempts to answer is whether or not the high rates of BMP adoption in the study area reflects diffusion among multiple farms, or if it only reflects the statistical average of intensive adoption of BMPs among just a few farms. In order to investigate this inquiry, an analysis was performed that identified the individual land parcels of the study area and counted the number of BMPs that fell on these individual parcels. The point data provided by the DCR specify the unique geographic locations for each individual BMP implementation and do not identify individual adopting farms. These point data, therefore, do not suffice as unique identifiers for individual adopting farms. The use of parcel data was the only immediate means of identifying individual farm properties.

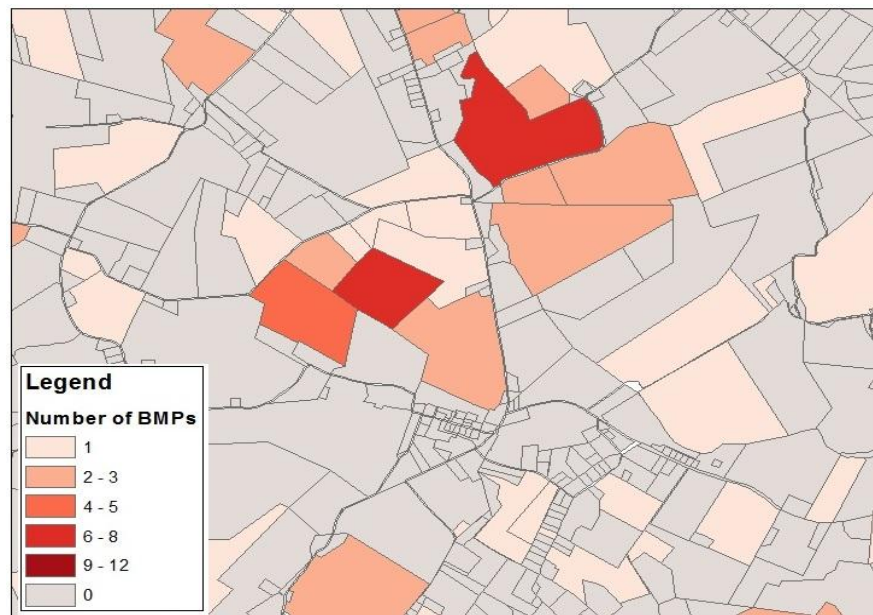


Figure 17. Sample of the map from analysis of BMP adoption intensity for each parcel in the study area.

Figure 17 represents a small piece of the parcel map that was populated with the BMPs. Due to privacy and confidentiality issues, the entire map may not be shown in order to avoid the identification of individual farms and their BMP adoption. The clip from the map was skewed off north as an additional precaution to protect the confidentiality of individual farms.

The parcels data used in this analysis are limited in their detail as they do not define the ownership of individual parcels nor do they provide distinction between different parcel zone types (residential, commercial, agricultural, etc.). Because of the limited detail of the data, this parcels analysis is limited in its ability to concretely identify whether or not the BMPs are being implemented by only a select number of highly innovative farmers or if BMPs are being implemented by multiple farmers across the community. However, the USDA Farm Census for 2007 lists the number and size of farms in this study area, thus providing adequate data to allow for empirical support of the premise that BMPs are being adopted by multiple farmer in the community (table 6).

Table 6. Description and Summary of the number and size of farms in each ZIP code of the analysis. (US Department of Agriculture, National Agricultural Statistics Service., 2007)

Name of ZIP Code	ZIP Code	1.0 TO 49.9 ACRES	50 TO 999 ACRES	1,000 ACRES OR MORE	Total Farms	% of total Watershed farms
Bridgewater	22812	57	116	0	173	5.5%
Mount Crawford	22841	56	68	3	127	4.1%
Mount Solon	22843	61	89	3	153	4.9%
Fort Defiance	24437	12	27	0	39	1.2%
Grottoes	24441	24	42	2	68	2.2%
Mount Sidney	24467	49	47	7	103	3.3%
Port Republic	24471	21	27	0	48	1.5%
Weyers Cave	24486	36	35	3	74	2.3%
Study Area Totals		316	451	18	785	25%

Because of the size of the study area and the number of parcels versus the number of farms in the study area, it can be assumed that what is shown in this analysis is diffusion of BMPs *within the entire community of the study area* and is not merely the diffusion of BMP adoption *amongst a small group of farms in the study area*. Having determined that BMP adoption events are not exclusive to only a handful of farmers in the community, the question arises as to whether support for some kind of contagion can be found by analyzing the time sequence maps of adoption diffusion and the parcels analysis map.

The small clip from the parcel map highlights well the reoccurring pattern seen throughout the ZIP code hotspots, that of individual high intensity BMP parcels being surrounded in close proximity by parcels with gradually lower intensities of BMP adoption activity (Figure 17). This pattern of “hot” parcels being surrounded by “warm” parcels of activity is consistent with a spatial diffusion contagion effect, perhaps even hierarchical contagion. The high adopting parcels are spread in different location across the study area, and surrounding them are parcels with medium participation and surrounding the parcels of medium participation are parcels of low participation. If these intensively adopting farms parcels are thought of in the sense of opinion leaders then this could be a case of hierarchical diffusion, as the points moved from the opinion leaders of the community and influential farmers to other less influential farmers in their proximity.

The sequence map of buffer BMP diffusion also seems to support the possible presence of hierarchical diffusion dynamics at play in the study area (figure 18). In the map sequence for Buffer BMPs, the first two years’ worth of adoption events are colored red, while the rest of the accumulating adoption events are shown in black. The buffer

BMP diffusion pattern suggests that the early adoptions of buffer BMPs seems to influence the adoption event occurring after them. The locations in close proximity to early adoption in 1996 and 2001 seem to have spurred other adoptions in their immediate proximity by the 2008 practice year.

Buffer BMP Diffusion, 1989-2008

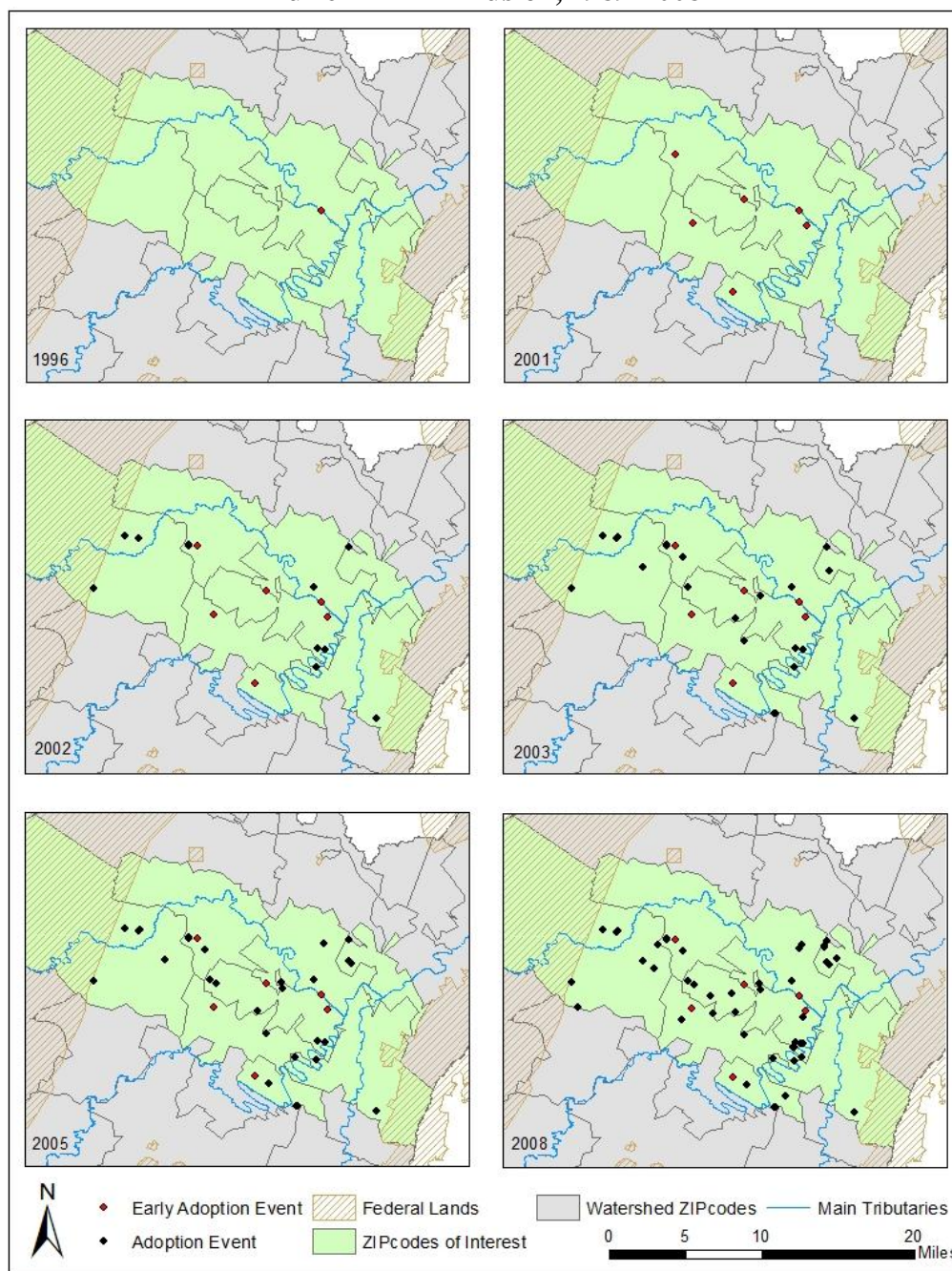


Figure 18. Map sequence showing the diffusion of buffer BMPs cumulatively in the study area, 1996-2008

Another possible reason for the intensity of BMP adoption activity in the study area relates to the study area being located within an immediate proximal distance to the confluence of the North River, Middle River, and South River to the Mainstem of the South Fork Shenandoah River. In the case of river proximity to farmland driving the intensity of BMP adoption in the study area, physical properties of the geography and hydrography could possibly be driving forces.

4.3 SUMMARY OF TEMPORAL AND SPATIAL ANALYSES

This chapter discussed the importance of temporal data analysis for greater understanding of possible direct and indirect influences on BMP adoption rates. The temporal analysis found two direct correlations with data to outside influences. Adoption frequencies of cover crop and waste management BMPs are positively correlated with availability of funding, cover crops being seemingly more tightly linked to funding than waste management. The temporal analysis of the BMP adoption types and their frequencies reinforced the already established finding that cover crops have enormously more adoption intensity in the study area and in the watershed than any other BMP type in the study. This pattern aligns itself well with the theory of innovation diffusion and its statements about the properties that determine an innovation's degree of adoptability. As stated before in the discussion of BMPs and innovation diffusion theory, cover crops BMPs have a high degree of adoptability because they have high levels of relative advantage, compatibility, trialability, and observability. It has relative advantage because the cost for implementation is low and the benefits include natural fertilization of fields and lessen erosion and soil loss. It is a BMP that is compatible with social norms and

farming tradition in this community. It is trialable, in that a farmer can plant a small field with a cover crop for a season or two to try the BMP with little cost and or fear of negative consequences. It is easily recognizable and observable in the field and a farmer can watch the production of a field and make judgments about the BMPs with no involvement by or risk to his or her farm. Cover crop BMPs have the excellent advantage of having very low complexity, thereby increasing the adoptability by the tradition farmer with would have no requirements for additional education to participate effectively.

The spatial analysis conducted on the BMP adoption data comprised analysis of time series map sequences, statistical analysis and choropleth map analysis. The Average Nearest Neighbor spatial statistics test was conducted on the cumulative BMP adoption data points in the study area as of the 2008 practice year for each of the different BMP types as well as for all of the BMP types combined. The average nearest neighbor test conducted for the cumulative total of all of the BMP types combined as of the 2008 practice year, showed statistical support for clustering behavior. Every individual BMP type, except waste management, also tested positive for clustering behavior. After clustering behavior of adoption events was statistically supported, the data were investigated using parcels data populated with the numbers of cumulative adoption events occurred within the boundaries of individual parcels of farm land. The aim of this particular spatial analysis was to establish support to determine whether or not the high rates of BMP adoption in the study area reflects diffusion among multiple farms, or if it only reflects the intensive adoption of BMPs among just a few farms. Due to the majority of farms within the study area being small to medium sized farms, it was surmised that there was enough evidence to support the supposition that what is shown by

these adoption data actually is diffusion of BMP adoption events throughout the entire community of farmers in the study area and is not merely the diffusion of BMP adoption events amongst a small group of actively participatory farms.

Once supportive statistical and analytical evidence was obtained for the spatial diffusion of BMP adoption across the study area, an additional mapping analysis was conducted to determine possible patterns present in the map sequences and parcels density that were consistent with theories of contagious spatial diffusion effects. Patterns were found in the dataset that were consistent with both contagious expansion and hierarchical contagious expansion diffusion models.

The temporal analysis of the BMP adoption diffusion suggests the following findings about intensity of adoption events in the subset study area:

When dedicated funding and promotion is given to a BMP, rates of that BMP's adoption by farmers will probably increase. This correlation between funding and participation was identified in adoption rates of cover crop and waste management BMPs. Rates are even more likely to increase when the promoted BMP is one with high levels of adoptability, as was the case with cover crop BMPs.

The spatial analysis of the BMP adoption had the following findings about forces of spatial diffusion on the intensity of adoption events in the study area:

Statistical support has been established to support the premise that clustering behavior is present in adoption event point data for the study area. However, the possibility of multiple BMP implementations on individual farms may partially explain this clustering behavior.

The spatial clustering of adoption events occurring in the study area is suggestive of hierarchical contagion models of diffusion. It is possible that opinion leaders of the community and influential farmers are influencing the adoption decisions of other farms in their proximity.

The geographic location of clustering of BMP adoption event points in the study area is consistent with previously noted possibilities that undetermined geographical or hydrological mechanisms may be influencing the diffusion and intensity of BMP adoption in the study area (i.e. the confluence of the North, Middle and South Rivers into the Mainstem of the South Fork Shenandoah River).

The findings and research in this thesis can aid conservation technicians, SWCD agents and VACS budget decision makers to better plan promotions and funding for VACS BMPs, as this dissertation identifies motivations and influential forces that are inherent in the BMPs, in the social system, and in the geographic location of the subset study area of the Watershed comprising ZIP codes with intense BMP adoption activity. This analysis of BMP adoption activity in the study area revealed the following about BMP adoption and possible forces at play that may have caused clustering of BMP adoption in the study area and presumably forces that influence the adoption of BMPs in the entire Watershed.

- 1.) *The geographic location of the study area.* The hotspot area is in close proximity of the confluence of the North River, Middle River and South River into the mainstem of South Fork Shenandoah River.
- 2.) *The promotion of priority practices.* The majority of BMPs that were most actively adopted were deemed “priority practices”. It is noteworthy, that 78% of the BMP adoption events that occurred in this study area were of BMPs that are designated by Virginia DCR in the 2011 VACS manual as “Priority Practices”. (Virginia Department of Conservation and Recreation, 2011).

- 3.) ***The properties of the BMPs that define their adoptability.*** There is a seemingly strong consistency between a particular BMP's adoptability and its intensity of adoption in the watershed. The BMP with the highest degree of adoptability, the cover crop BMP, was also the most widely and actively adopted BMP in the watershed. In addition, the two BMPs with the lowest degree of adoptability, nutrient management and buffer BMPs, were also the least adopted BMPs in the Watershed.
- 4.) ***Dynamics of hierarchical contagion models of diffusion.*** It is possible that opinion leaders of the community and influential farmers are influencing the adoption decisions of other farms in their proximity.

5. FURTHER RESEARCH & CONCLUSIONS

This chapter provides a brief description of the limitations of this study and also provides recommendations for further studies based off of the findings presented in the work of this thesis.

LIMITATIONS:

Two major limitations revealed about this data were 1.) that the VACS BMP data does not consider private, non-cost share BMPs and 2.) the data do not provide any type of unique identifiers to determine different adopting farms.

In reference to exclusion of other non VACS voluntary BMPs from the analysis, there are many farmers who have implemented many similar BMPs to those featured in VACS on their farms especially those farmers who are Mennonites who are not represented in this dataset because they do not accept financial assistance from the government. There are other very proactive farmers in the community who implement BMPs voluntarily because they are environmentally conscious and usually in a higher socioeconomic bracket than most farmers in the community.

In reference to the lack of unique farm identifiers, this deficiency in the data created barriers to concretely determining the number of individual farms that adopted BMPs. If unique identifiers for farms were supplied in the data for each BMP implementation, then it would have been possible to conduct even more in-depth study on the BMP adoption events on individual farms in the study area.

RECOMMENDATIONS FOR FURTHER STUDY:

It was difficult to address the possibility of clustering being skewed by repeated BMP adoptions by a single Farmer. This problem could be further explored by more in depth analysis of the data if the researcher could acquire special permissions from counties to see more details on the parcels' databases (i.e. farm ownership). This exploration of data would be considerably time consuming but the insights that could be gained from such research would better answer the question of how BMP adoption events diffused across the different farms in the community. Upon completing such research, one would also be able to draw conclusion about the correlation between the farms' characteristics (i.e. farm size, farm income, proximity to streams) and the farms' frequencies of VACS BMP adoption.

The purpose of this study was to zoom in on the subset of ZIP codes in the Watershed with the most BMP adoption activity to find any underlying forces or factors that influence VACS BMP adoption. It is recommended that the findings from the analyses of the study area be used to analyze the entire Watershed as a whole and compare the remainder of the Watershed ZIP codes with those of the subset study area. Knowing what factors influence the adoption of BMPs in the study area, it is important to now move from the micro scale back to the macro scale to test the applicability of these factors on the entire Watershed. The findings of this thesis described *what* dynamics were at play in the VACS BMP adoption diffusion through the Watershed. The aforementioned recommendations for research are the next steps to take in order to explore *why* there is clustering behavior of BMP adoption events in the Watershed.

APPENDIX 1. MAP SEQUENCES OF DIFFUSION OF BMP ADOPTION

The Time series Map sequences from described in Chapter 4 are included in this appendix.

Data Source for Maps: Virginia Department of Conservation and Recreation, 2008, unpublished data.

Buffer BMP Diffusion, 1989-2008

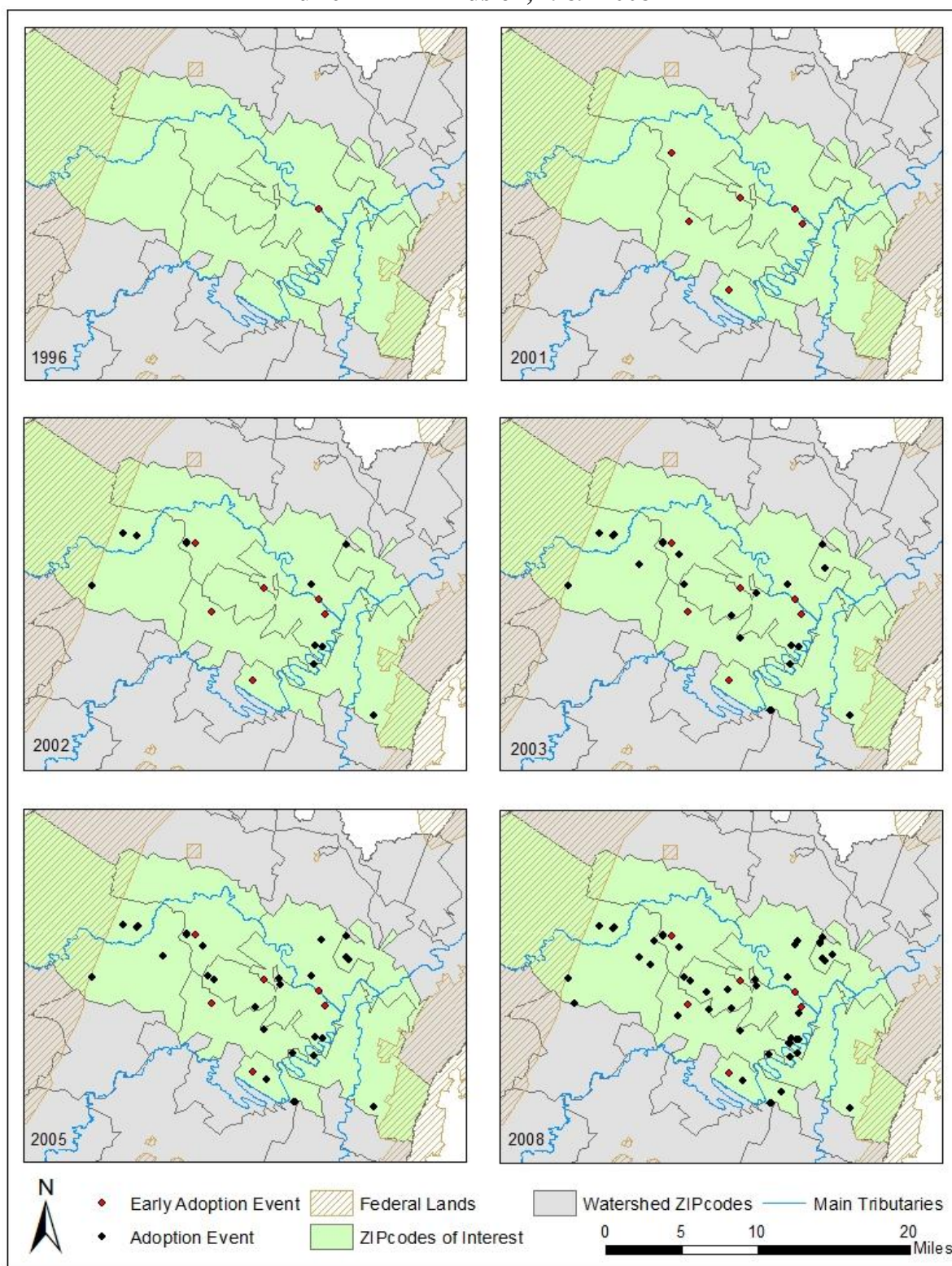


Figure 19. Map sequence showing the diffusion of buffer BMPs cumulatively in the study area, 1996-2008

Cover Crop BMP Diffusion, 1989-2008

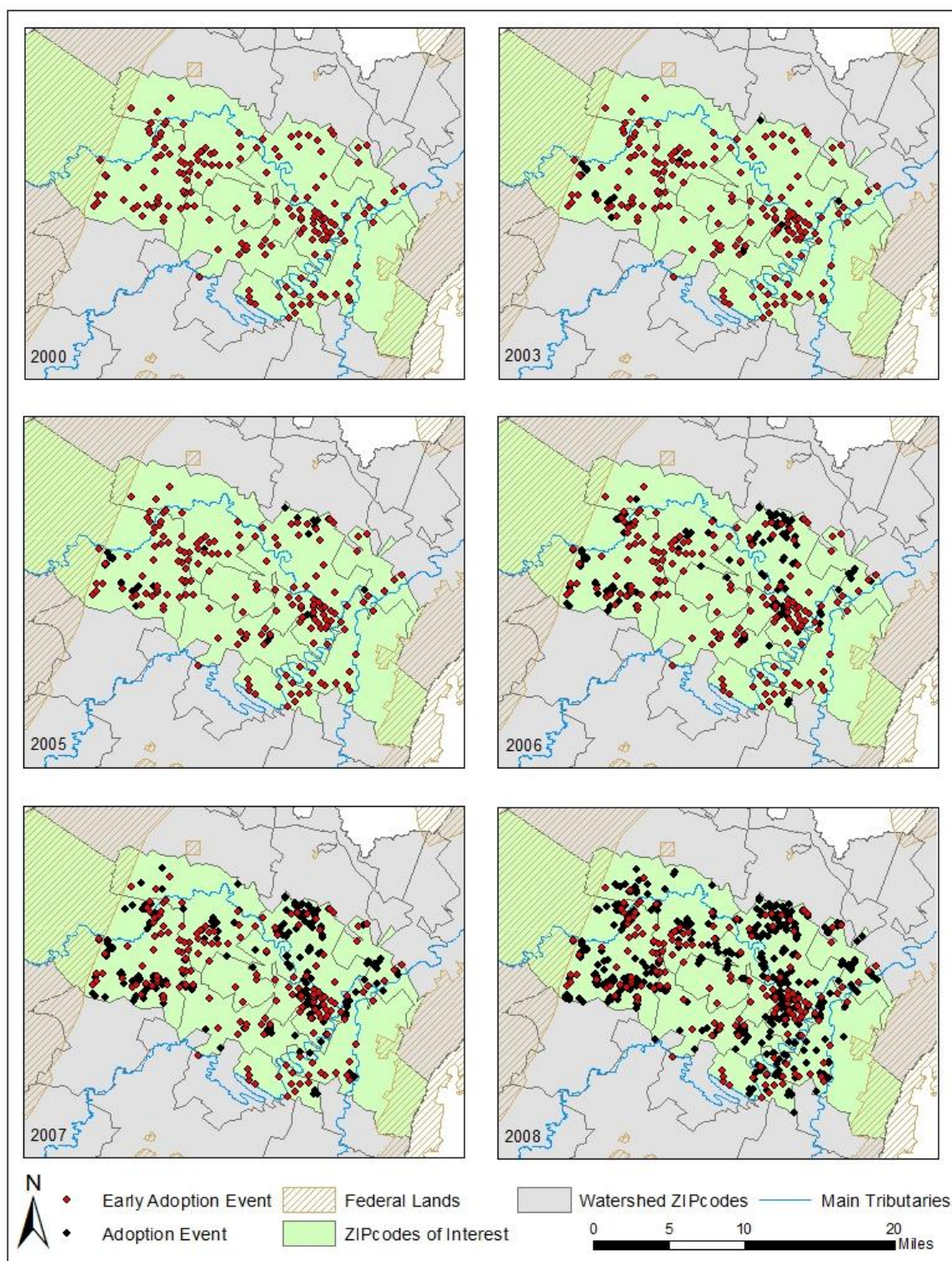


Figure 20. Map sequence showing the diffusion of cover crop BMPs cumulatively in the study area, 1989-2008

Cropland Drainage BMP Diffusion, 1989-2008

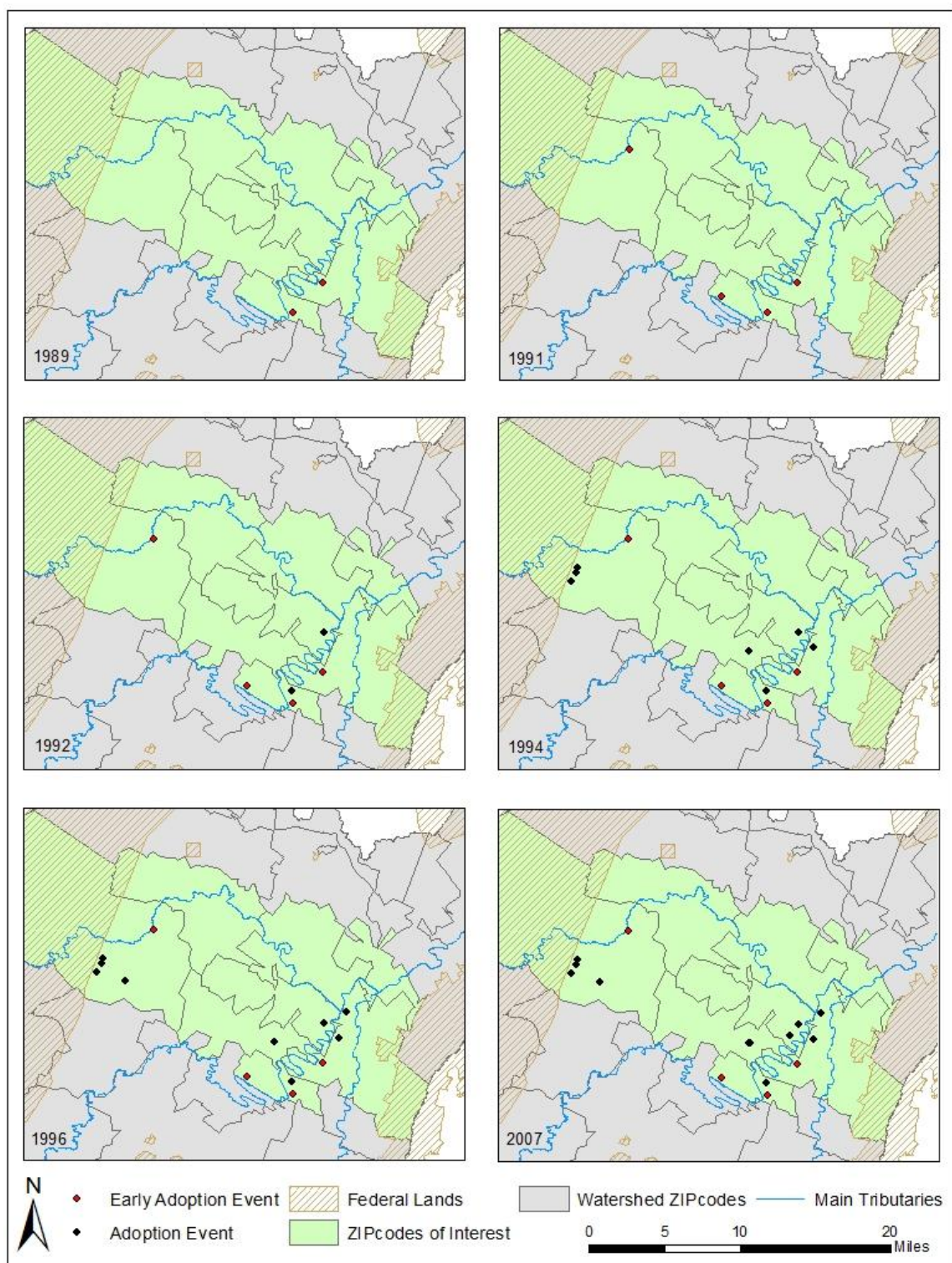


Figure 21. Map sequence showing the diffusion of cropland drainage BMPs cumulatively in the study area, 1989-2008

Livestock Exclusion BMP Diffusion, 1989-1998

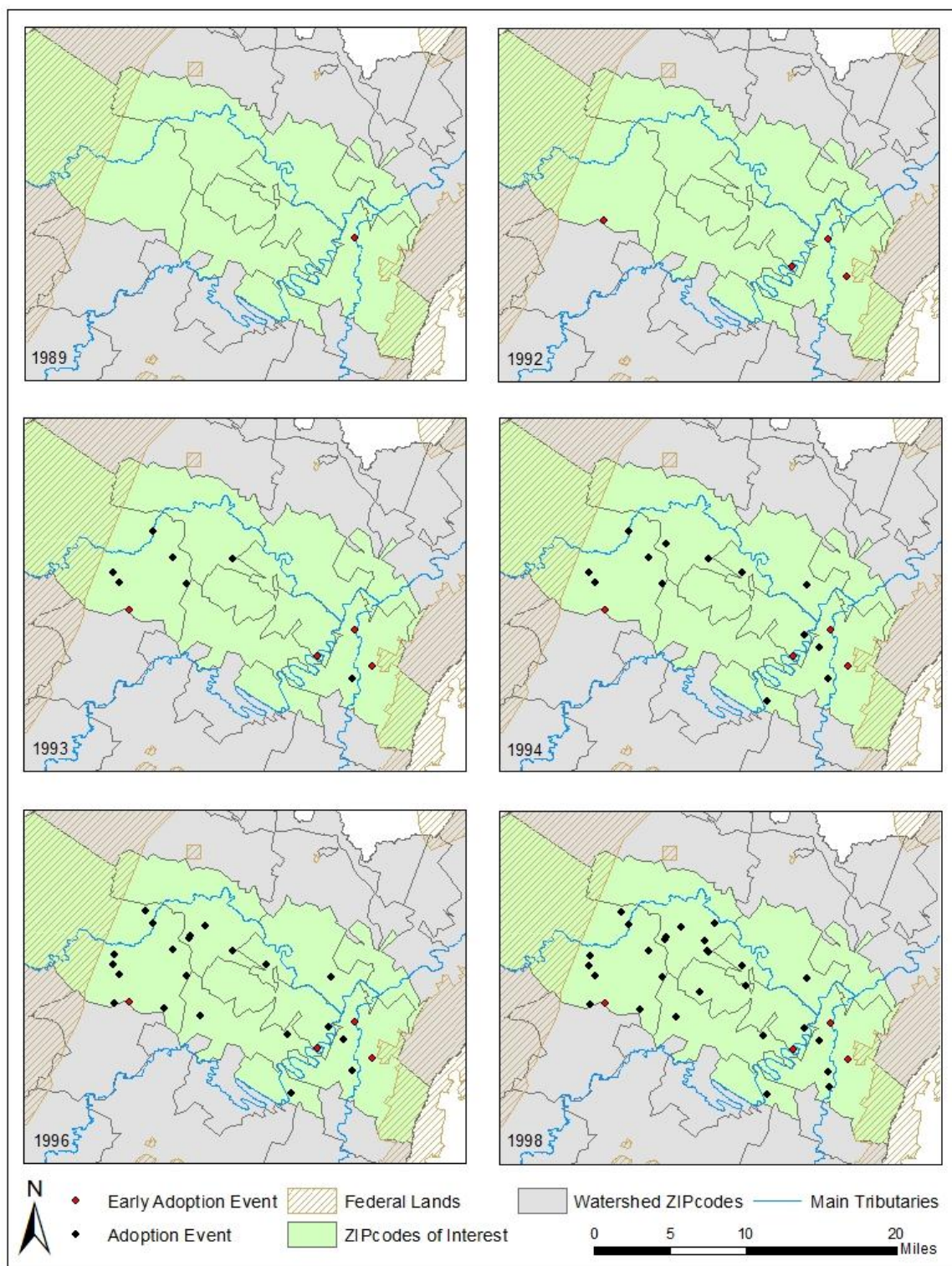


Figure 22. Map sequence showing diffusion of livestock exclusion BMPs cumulatively in the study area, 1989-1998

Livestock Exclusion BMP Diffusion, 1999-2008

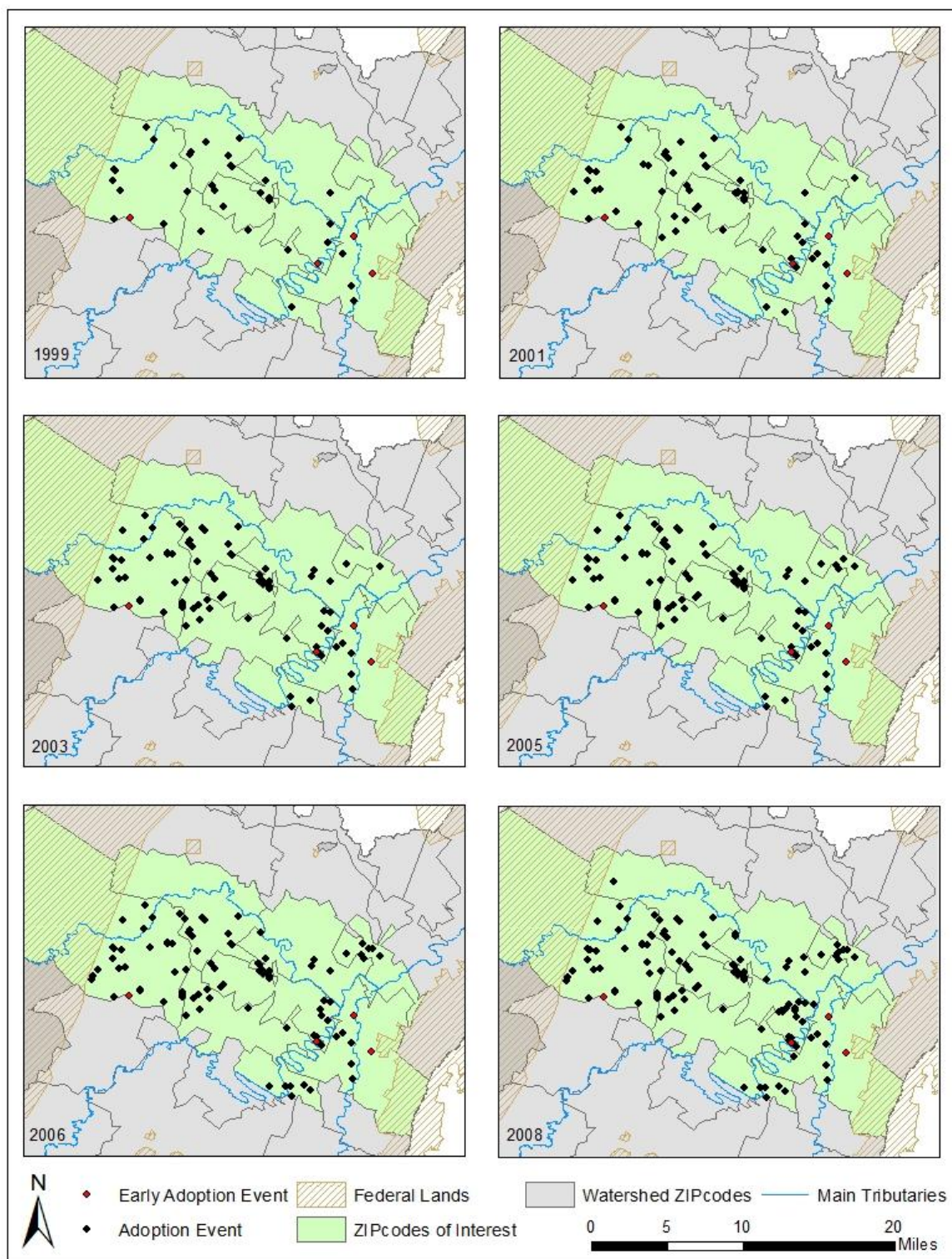


Figure 23. Map sequence showing diffusion of livestock exclusion BMPs cumulatively in the study area, 1989-1998

Nutrient Management BMP Diffusion, 2001, 2003, 2008

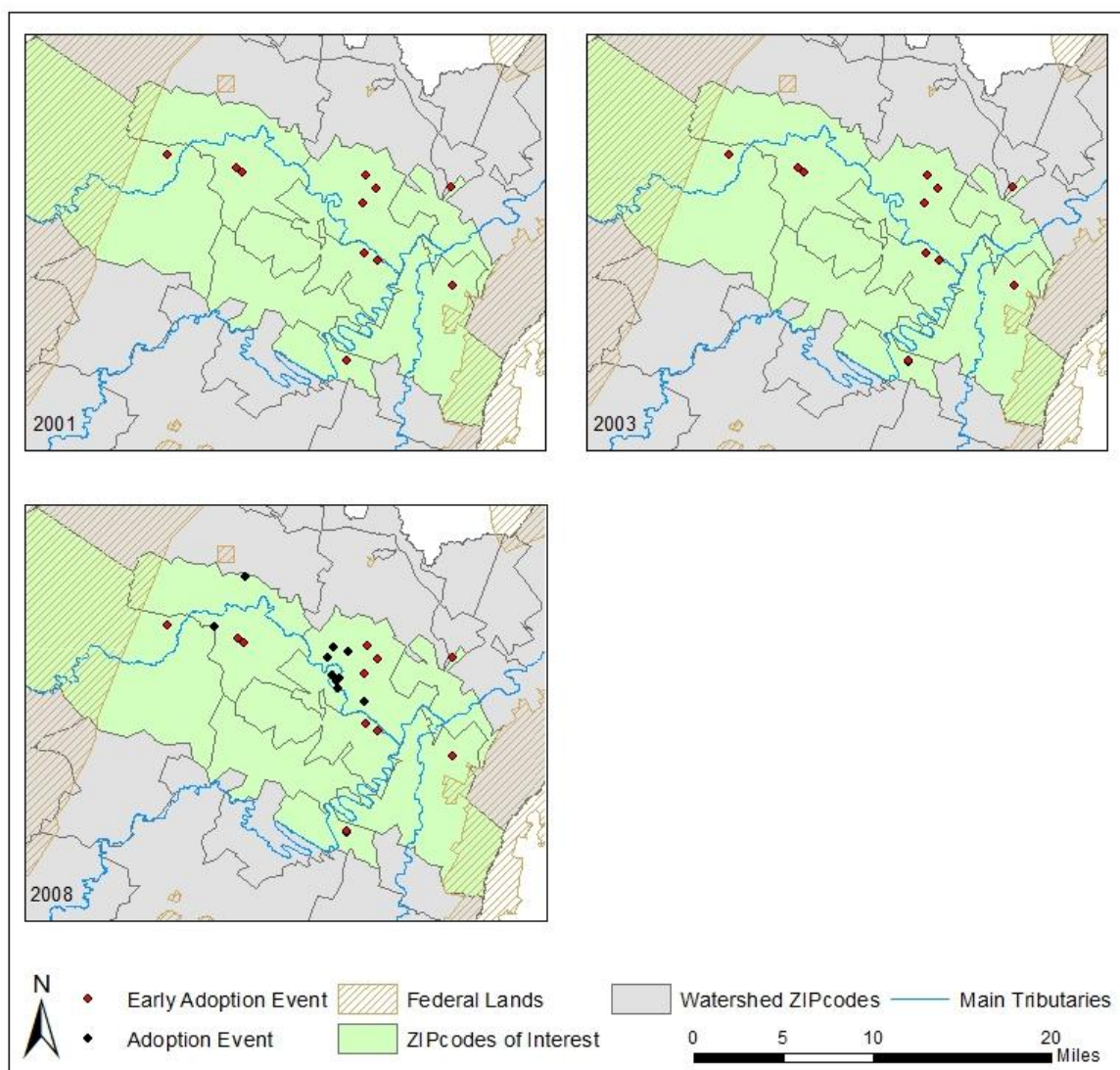


Figure 24. Map sequence showing the diffusion of nutrient management BMPs cumulatively in the study area, 2001, 2003, & 2008.

Permanent Cover BMP Diffusion, 1989-1998

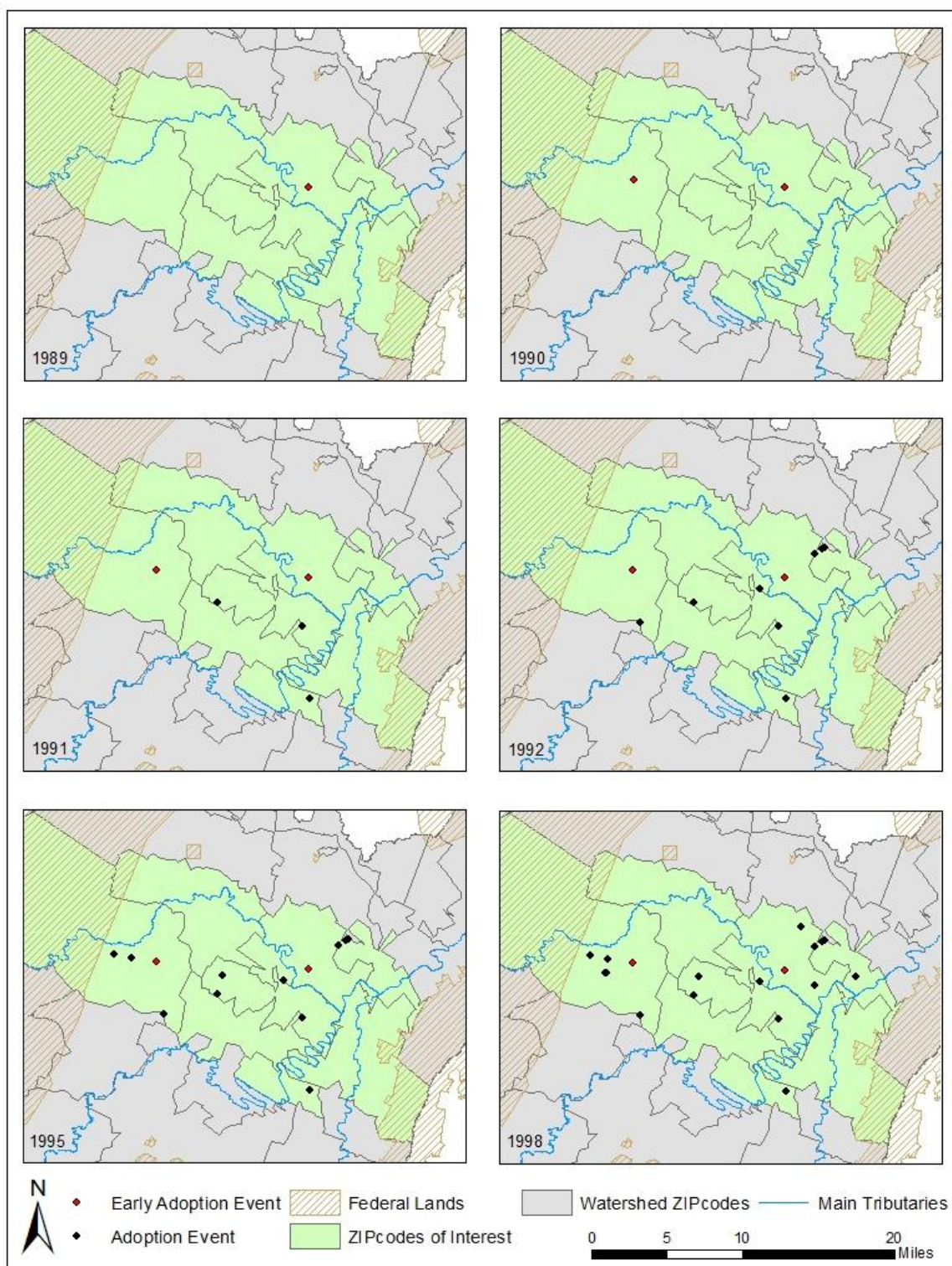


Figure 25. Map sequence showing diffusion of permanent cover BMPs cumulatively in the study area, 1989-1998

Permanent Cover BMP Diffusion, 1999-2008

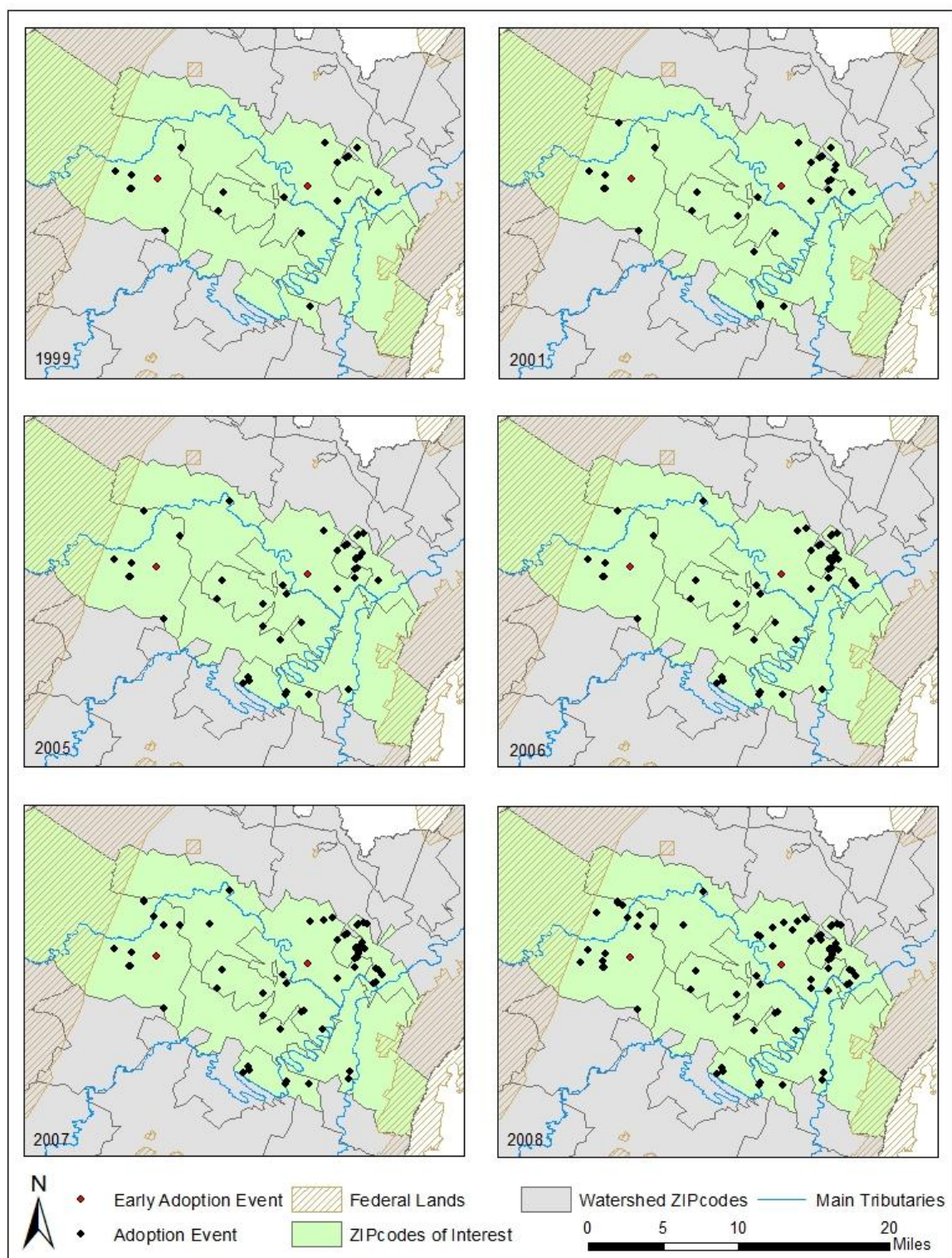


Figure 26. Map sequence showing diffusion of permanent cover BMPs cumulatively in the study area, 1999-2008

Waste Management BMP Diffusion, 1989-1999

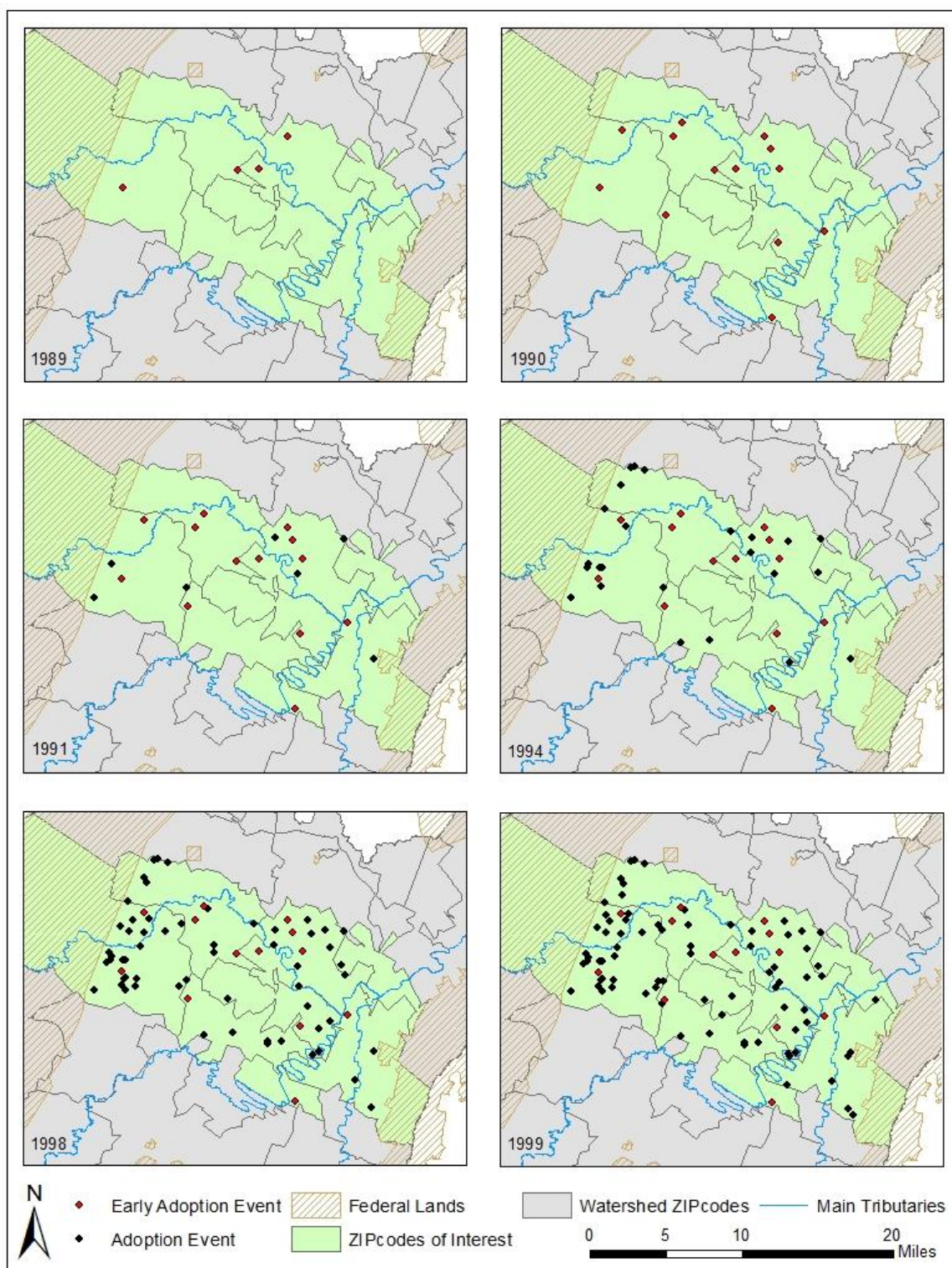


Figure 27. Map sequence showing diffusion of waste management BMPs cumulatively in the study area, 1989-1999

Waste Management BMP Diffusion, 2000-2008

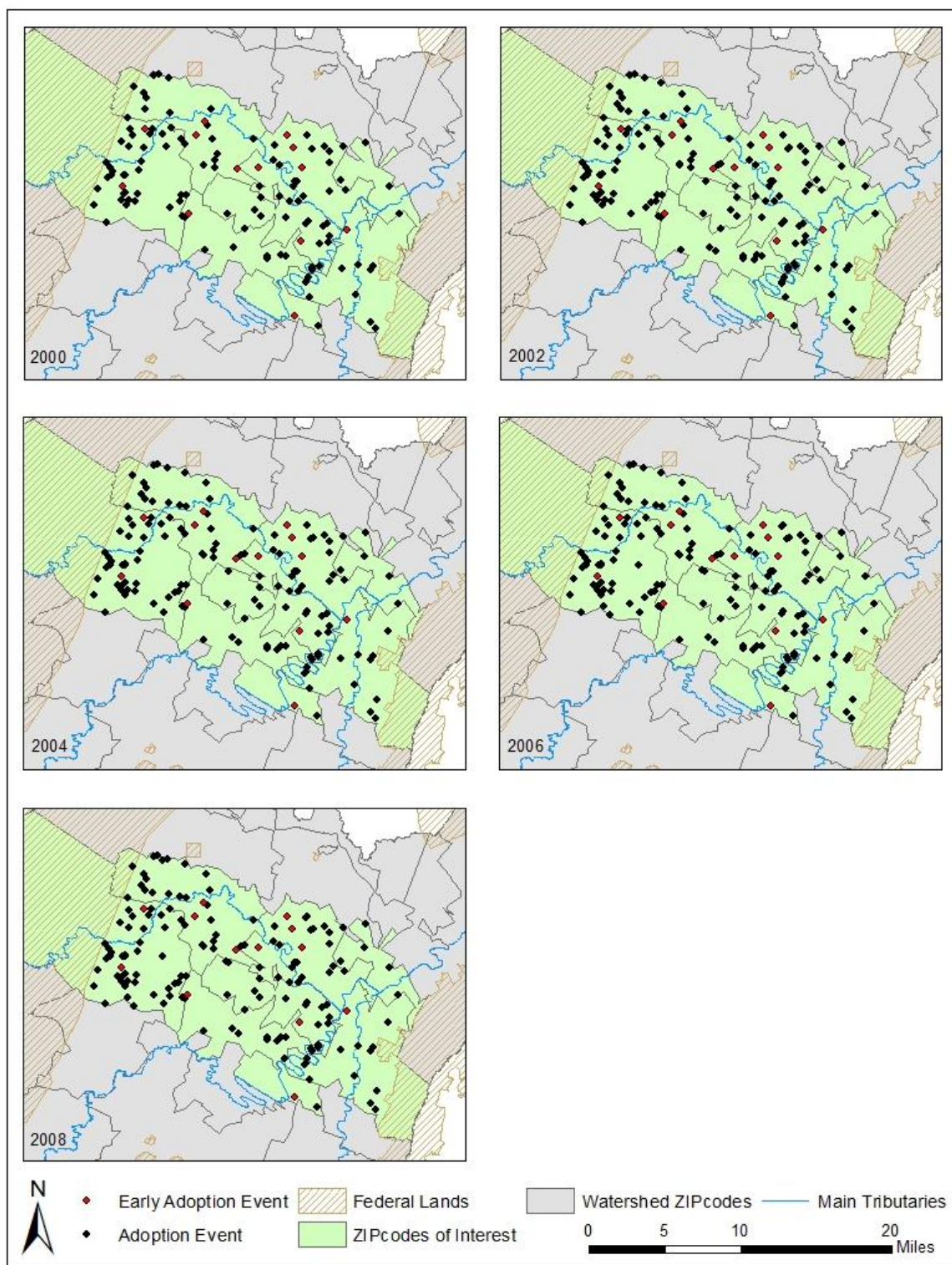


Figure 28. Map sequence showing diffusion of waste management BMPs cumulatively in the study area, 2000-2008

REFERENCES

- Alvarez, D., Cranor, W., Perkins, S., Schroeder, V., Werner, S., Furlong, E., et al. (2008). *Reconnaissance of persistent and emerging contaminants in the Shenandoah and James River basins, Virginia, during spring of 2007*. Reston, Virginia: U.S. Geological Survey.
- Aust, M. (2010). Riparian forest established by the Conservation Reserve Enhancement Program in Virginia: Implications for managers. *Journal of Soil and Water Conservation* , 65 (2), 57A.
- Berger, T. (2001). Agent-based spatial models applied to agriculture: a simulation tool for technology diffusion, resource use changes and policy analysis. *Agricultural Economics* , 25, 245-260.
- Bradburn, B. N., Aust, W. M., Dolloff, C. A., Cumbia, D., & Creighton, J. (2010). Evaluation of riparian forests established by the Conservation Reserve Enhancement Program (CREP) in Virginia. *Journal of Soil and Water Conservation* , 65 (2), 105-112.
- Brakebill, J. W., Ator, S. W., & Schwarz, G. E. (2010). Sources of suspended-sediment flux in streams of the Chesapeake Bay watershed: A regional application of the SPARROW model. *Journal of the American Water Resources Association* , 46 (4), 757-776.
- Ciciotti, E., Alderman, N., & Thwaites, A. (1990). *Technological change in a spatial context: theory, empirical evidence and policy*. Berlin: Springer-Verlag.
- Clearfield, F., & Osgood, B. T. (1986). *Sociological aspects of the adoption of conservation practices*. Washington, D.C.: Soil Conservation Service.
- Cromley, E. K., & McLafferty, S. L. (2002). *GIS and public health*. New York: The Guilford Press.
- Fuglie, K. O., & Kascak, C. A. (2001). Adoption and diffusion of natural resource conserving agricultural technology. *Review of Agricultural Economics* , 23 (2), 386-403.

- Gilbert, P. M., Trice, T. M., Michael, B., & Lane, L. (2005). Urea in the tributaries of the Chesapeake and costal bays of Maryland. *Water, Air, and Soil Pollution* , 160, 229-243.
- Greiner, R., Patterson, L., & Miller, O. (2009). Motivations, risk perceptions and adoption of conservation practices by farmers. *Agricultural Systems* , 99, 86-104.
- Grübler, A. (2010). Time for a change: on the patterns of diffusion of innovation. *Daedalus* , 125 (3), 19-42.
- Habron, G. B. (2004). Adoption of conservation practices by agricultural landowners in three Oregon watersheds. *Journal of Soil and Water Conservation* , 59 (3), 109-115.
- Haggett, P. (2000). *The geographical structure of epidemics*. Oxford: Oxford University Press.
- Jackson-Smith, D. B., Halling, M., de la Hoz, E., McEvoy, J. P., & Horsburgh, J. S. (2010). Measuring conservation program best management practice implementation and maintenance at the watershed scale. *Journal of Soil and Water Conservation* , 65 (6), 413-423.
- Khanna, M. (2001). Sequential adoption of site-specific technologies and its implications for nitrogen productivity: a double selectivity model. *American Journal of Agricultural Economics* , 83 (1), 35-51.
- Kim, S., Gillespie, J. M., & Paudel, K. P. (2005). The effect of socioeconomic factors on the adoption of best management practices in beef cattle production. *Journal of Soil and Water Conservation* , 60 (3), 111-120.
- Koch, T. (2005). *Cartographies of disease: maps, mapping and medicine*. Redlands, California: ESRI Press.
- Koebel, C. T., Papadakis, M., Hudson, E., & Cavell, M. (2003). *The diffusion of innovation in the residential building industry*. Blacksburg, Virginia: Center for Housing Research, Virginia Polytechnic Institute and State University.

- Kümmerer, K., Held, M., & Pimentel, D. (2010). Sustainable use of soils and time. *Journal of Soil and Water Conservation* , 65 (2), 141-149.
- Lambert, D., Schaible, G. D., Johansson, R., & Vasavada, U. (2007). The value of integrated CEAP-ARMS survey data in conservation program analysis. *Journal of Soil and Water Conservation* , 62 (1), 1-10.
- Landers, J. (2010, July). Federal agencies release plan for improving health of the Chesapeake Bay. *Civil Engineering* , pp. 28-30.
- Lawson, A. B. (2006). *Statistical methods in spatial epidemiology* (2nd Edition ed.). Chichester, West Sussex, England: John Wiley & Sons Ltd.
- Lemke, A. M., Lindenbaum, T. T., Perry, W. L., Herbert, M. E., Tear, T. H., & Herkert, J. R. (2010). Effects of outreach on the awareness and adoption of conservation practices by farmers in two agricultural watersheds of the Mackinaw River, Illinois. *Journal of Soil and Water Conservation* , 65 (5), 304-315.
- Mizel, N., Papadakis, M., Degner, K., Shepard, K., & Havinga, M. (2008). *South Fork Shenandoah: Rapid Watershed Assessment*. Staunton, Virginia: Virginia Department of Conservation and Recreation.
- Molnar, J. J., Bitto, A., & Brant, G. *Core conservation practices: paths and barriers perceived by small and limited resource farmers*.
- Morrill, R., Gaile, G. L., & Thrall, G. I. (1988). *Spatial Diffusion*. Newbury Park, California: Sage Publication, Inc.
- Napier, T. L., & Bridges, T. (2002). Adoption of conservation production systems in two Ohio watersheds: A comparative study. *Journal of Soil and Water Conservation* , 57 (4), 229-235.
- Napier, T. L., Tucker, M., & McCarter, S. (2000). Adoption of conservation production systems in three midwest watersheds. *Journal of Soil and Water Conservation* , 55 (2), 123-134.
- Nowak, P. J., & Cabot, P. E. (2004). The human dimension of resource management programs. *Journal of Soil and Water Conservation* , 59 (6), 128A-135A.

- Orzetti, R., Jones, C., & Murphy, R. F. (2010). Stream condition in piedmont streams with restored riparian buffers in the Chesapeake Bay watershed. *Journal of the American Water Resources Association* , 46 (3), 473-485.
- Padel, S. (2001). Conversion to organic farming: A typical example of diffusion of innovation? *Sociologia Ruralis* , 41 (1), 40-61.
- Papadakis. (2008). *Stakeholder analysis and its implications for watershed conservation programming, education, and outreach*. Harrisonburg, Virginia: Center for Energy and Environmental Sustainability.
- Parra-Lopez, C., De-Haro-Giménez, T., & Calatrava-Requena, J. (2007). Diffusion and Adoption of Organic Farming in the Southern Spanish Olive Groves. *Journal of Sustainable Agriculture* , 30 (1), 105-151.
- Prokopy, L. S., Floress, K., Klotthor-Weinkauff, D., & Baumgart-Getz, A. (2008). Determinants of agricultural best management practice adoption: evidence from literature. *Journal of Soil and Water Conservation* , 63 (5), 300-311.
- Reddy, G. V., & Sudharani, V. (2007). *Communication and diffusion of agricultural innovations: mass media communication*. Andhra Pradesh, India: National Institute of Agricultural Extension Management (MANAGE).
- Rogers, E. M. (1983). *Diffusion of Innovations* (3rd ed.). New York: The Free Press.
- Ruhl, H. A., & Rybicki, N. B. (2010). Long-term reductions in anthropogenic nutrients link to improvements in Chesapeake Bay habitat. *PNAS* , 107 (38), 16566–16570.
- Russell, M. J., Weller, D. E., Jordan, T. E., Sigwart, K. J., & Sullivan, K. J. (2008). Net anthropogenic phosphorus inputs: spatial and temporal variability in the Chesapeake Bay region. *Biogeochemistry* , 88, 285-304.
- Secchi, S., Gassman, P. W., Jha, M., Kurkalova, L., Feng, H. H., Campbell, T., et al. (2007). The cost of cleaner water: Assessing agricultural pollution reduction at the watershed scale. *Journal of Soil and Water Conservation* , 62 (1), 10-21.

- Sullivan, D. G., & Batten, H. L. (2007). Little River Experimental Watershed. Tifton, Georgia, United States: A historical geographic database of conservation practice implementation. *Water Resources Research* , 43, 1-5.
- Sunding, D., & Zilberman, D. (1999). *The agricultural innovation process: research and technology adoption in a changing agricultural sector*. Berkeley, CA: Department of Agricultural and Resource Economics, UC Berkeley.
- Tarde, G. (1903). *The Laws of Imitation*. New York: Holt.
- US Department of Agriculture, National Agricultural Statistics Service. (2002). *US Census of Agriculture*.
- US Department of Agriculture, National Agricultural Statistics Service. (2007). *US Census of Agriculture*.
- Vijayabhinandana, B. (2007). *Communication and diffusion of agricultural innovations: diffusion of agricultural innovations*. Andhra Pradesh, India: National Institute of Agricultural Extension Management (MANAGE).
- Virginia Agribusiness Council. (2010, June). *Chesapeake Bay TMDL Briefing Paper: June 2010*. Retrieved March 9, 2011, from Virginia Agribusiness Council: www.va-agribusiness.org/public/pages/index.cfm?pageid=433
- Virginia Department of Conservation and Recreation. (2008). Agricultural Cost Share Database.
- Virginia Department of Conservation and Recreation. (2011). *Program Year 2011: Virginia Agricultural Cost Share (VACS) BMP manual*. Richmond, Virginia: Virginia Department of Conservation and Recreation.
- Wejnert, B. (2002). Integrating models of diffusion innovations: a conceptual framework. *Annu. Rev. Sociol.* , 28, 297-326.
- Yates, A. G., Bailey, R. C., & Schmindt, J. A. (2007). Effectiveness of best management practices in improving stream ecosystem quality. *Hydrobiologia* , 583, 331-344.